Castle Mountain Mine
San Bernardino County, California
Research and Reclamation, 1990-2005
Summary Report

Prepared for:

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TABLE OF CONTENTS

TABLES

FIGURES

ABBREVIATIONS

BLM	Bureau of Land Management
CMM	Castle Mountain Mine
County	San Bernardino County
EIS/EIR	Environmental Impact Statement/Environmental Impact Report EIS/EIR
FAA	formalin-aceto-alcohol
INVAM	International VAM Fungus Collection
IUM	Infection Unit Method (for assessment of VAM)
OMR	California Office of Mine Reclamation
RRC	Revegetation Review Committee
SDSU	San Diego State University
SPHA	Salvaged plant holding area
UNLV	University of Nevada-Las Vegas
VAM	Vesicular-arbuscular mycorrhizae
Viceroy	Viceroy Gold Corporation
WHC	Water-holding capacity

1.0 INTRODUCTION

Castle Mountain Mine (CMM), located in the south-central Mojave Desert, actively mined for gold for the decade between 1991 and 2001. During this period not only did CMM sponsor and pursue reclamation and revegetation procedures as required by the Bureau of Land Management (BLM) and the County of San Bernardino, but they also supported a highly productive research program with as many as three full-time revegetation personnel on staff. The research was initiated largely to identify and test for successful revegetation and reclamation procedures, which up to that point had not been standardized for any mining ventures, let alone those in the extreme conditions of the Mojave Desert.

The following report summarizes the research, reclamation, and revegetation activities conducted at CMM. The majority of research objectives pursued at CMM were directly relevant to reclamation and revegetation procedures, and where possible, results from the research were used to the benefit of the required reclamation processes.

Before active mining at CMM began, a reclamation plan (Viceroy Gold Corporation, 1990) was designed and submitted to the BLM and San Bernardino County in 1990. This Mine Plan and Reclamation Plan, v.2.0, was revised in June 1998 (Viceroy Gold Corporation 1998), and the County issued revised Condition of Approval. The details of these plans are not reproduced here because our focus is not on the intention of the original design, but rather what was executed in the field. Therefore our report emphasizes the reclamation and revegetation activities that were actually performed, regardless of their inclusion in the reclamation plans, and the efficacy of these activities as measured in research (Sections 8.0 - 10.0) and monitoring. Indeed, as research both at Castle Mountain and on larger issues of reclamation advanced over the 15 years since the inception of this project, it was agreed that reclamation procedures considered to be standard in the late 1980s and early 1990's could be improved with modified techniques. Reclamation and revegetation procedures actually carried out at CMM were reported in the eleven Annual Revegetation Reports submitted between 1992 and 2002 and are described herein.

Because the series of Annual Revegetation Reports has been the primary source of information for this document, when referring to any of these Revegetation Reports we determined it most economical to use the simple phrase "1st Report, 1992," "2nd Report, 1993," and so forth. Other documents will be adequately specified for the reader to identify in the References (Section 12.0).

All species identified on CMM property are listed in Appendix A. Other species used in research and/or reclamation that are not necessarily endemic to CMM are identified in association with each specific project. In an attempt to strike agreement among differing taxonomic references, all species herein are identified with their most recent taxonomic name as identified in Baldwin *et al.* (2002). Throughout the majority of this report species are referred to by their common names; Latin nomenclature is provided for endemic species in Appendix A and for all other species in project descriptions or other appropriate references.

2.0 DESCRIPTION OF CASTLE MOUNTAIN MINE

In addition to the descriptions below of the location, physiography, vegetation, and climate of Castle Mountain Mine, the site has a history of grazing – and overgrazing – by cattle (1st Report, 1992), which were introduced to the area in the 1880s (3rd Report, 1994). Its history of intensive grazing is partly the result of CMM's proximity to the historic town of Hart, which operated a mine beginning in 1907. Very little is in fact known about the vegetation in the East Mojave National Scenic Area, where CMM is located, before grazing was introduced (2nd Report, 1993). It is understood that Utah juniper and catclaw were used primarily for firewood and mine beams, although the quantities in which either occurred on CMM are unknown (3rd Report, 1994).

2.1 LOCATION

Castle Mountain Mine is located in the south-central Mojave Desert, in the eastern portion of San Bernardino County, in the northeast of the Lanfair Valley, and in the Castle Mountains area about 17 miles southeast of Nipton, California and five miles west of the Nevada state line (Figure 1). The Castle Mountains and Piute Range lie to the east, the New York Mountains are to the northwest, and the Providence Mountains are to the southwest. The CMM site is in Sections 24, 25, 26, the southern half of Section 13, and the southeast quarter of Section 14, Township 14 North, Range 17 East, San Bernardino Baseline and Meridian; and the western portions of Sections 19 and 20, Township 14 North, Range 18 East, San Bernardino Baseline and Meridian (1st Report, 1992). The 2,735-acre mine ceased active mining operations in May 2001 and has been in closure and a final reclamation process for the last four years.

2.2 PHYSIOGRAPHY

Castle Mountain Mine is located within the Great Basin physiographic province and is characterized by uplifted ranges surrounding lower, alluvial basins. The Castle Mountains form what was once a large Miocene caldera; these as well as the Piute and a portion of the New York Ranges are characterized by extrusive Miocene volcanics. CMM is in the northeast of the Lanfair Valley, which is underlain by the Miocene-age volcanics. Lanfair Valley has filled to varying depths with Quaternary alluvium and, to the north, infrequently exposed residual Pleistocene deposits from an earlier alluvial sequence, probably associated with the formation of pluvial lake deposits in the southern portion of the valley. The New York Mountains are composed variably of ancient pre-Cambrian metamorphic rocks, extrusive Miocene volcanics, and Cretaceous granitics. The central portion of this range lies within a fault zone which exposes early Paleozoic sediments (3rd Report, 1994).

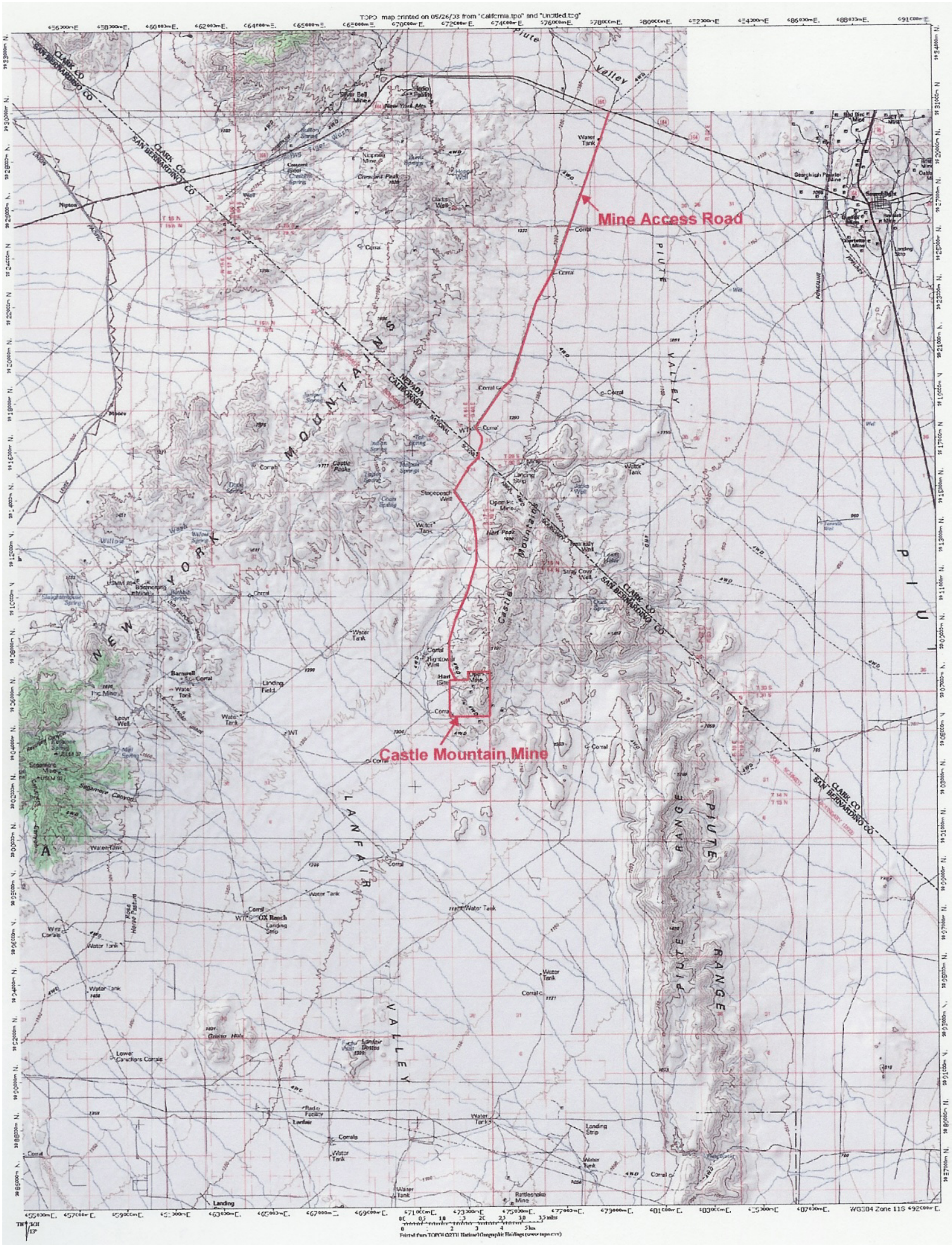


Figure 1. Castle Mountain Mine Location.

The Lanfair Valley is characterized by Quaternary sediments surrounded by alluvial fans, sloping bajadas, and uplifted mountains (3rd Report, 1994). CMM is in an area of rolling desert valley floor and bench intergrading onto toeslope benches and foothills and the Castle Mountain Range. Elevations of CMM range from 1260 to 1561 m. Soils in the CMM area derive from alluvium in the valley floors and benches and from primary minerals (rock and gravel) on hillsides (1st Report, 1992).

2.3 VEGETATION

Vegetation in the region surrounding CMM includes piñon-juniper woodlands at higher elevations, Joshua tree woodland and creosote bush scrub in the valleys, and a grass-dominated understory. In the immediate vicinity of CMM vegetation includes Joshua tree woodland, creosote bush scrub, and blackbrush scrub. No piñon pine has been identified on the CMM property, but isolated patches of Utah juniper have been located on north-facing slopes between 1380 and 1400 m elevation. Isolated juniper has also been observed along the Searchlight access route (3rd Report, 1994).

2.4 CLIMATE

The CMM area typically has a bimodal climatic pattern, receiving most precipitation during the winter and a smaller flush in late summer/early fall (Figure 2). Precipitation is the major factor controlling soil moisture and subsequent plant germination, growth, and survival. Average annual precipitation from 1991 to 2004 was 8.1 inches (Figure 3).

Plant performance reflects trends in precipitation. As observed in 1995, for example, relatively high precipitation is associated with high flower, fruit, and seed production in some species, although not all. High precipitation may also induce some species to flower that don't bloom during drought years (5th Report, 1996).

2.5 CMM MINING HISTORY

CMM mining operations were approved in October 1990 and operations started in April 1991. CMM mining methods used open-pit mining and ore crushing, grinding, and leaching. The mine operated three open pits – Oro Belle, Jumbo, and Lesley Ann – in addition to two overburden sites, one leach pad and mill area, one crushing area, and administrative buildings and facilities. The first gold at CMM was extracted in February 1992. CMM completed active mining in May

2001 and began closure and reclamation procedures in mid-2001; as of 2002, the Lesley Ann pit had been backfilled (11th Report, 2002).

Figure 2. 1991-2004 monthly precipitation averages.

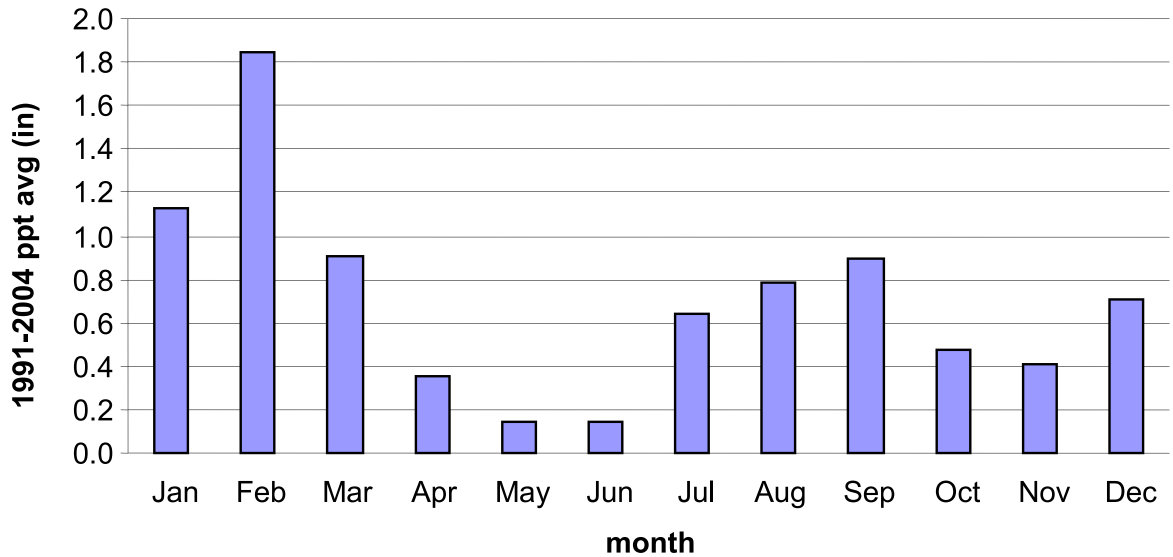
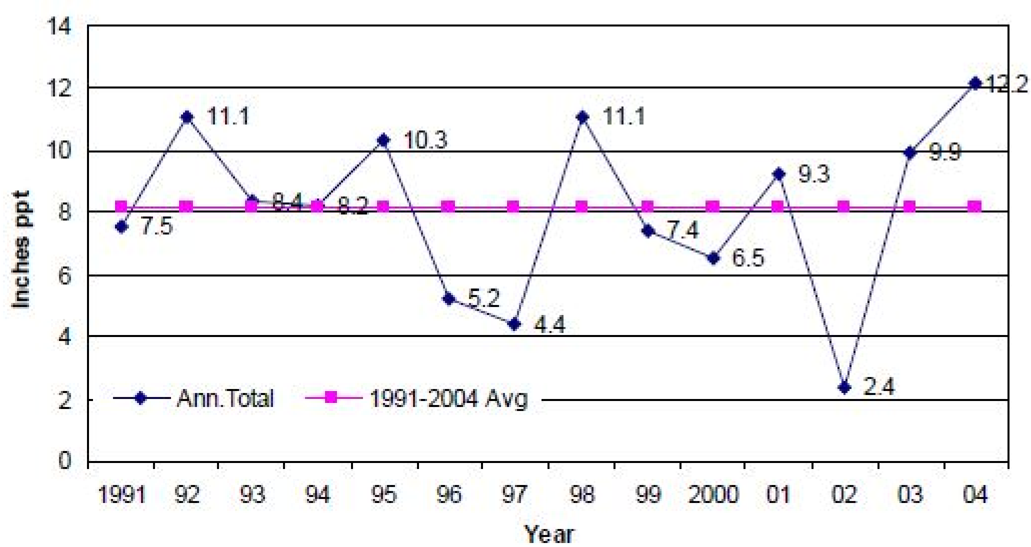


Figure 3. Average annual precipitation from 1991 to 2004 at CMM (8.1 inches) compared to yearly totals.



3.0 RECLAMATION REQUIREMENTS AND ADMINISTRATION

All reclamation and research programs (see Sections 4.0 - 9.0) stipulated by the Bureau of Land Management (BLM) and San Bernardino County (County) were implemented and completed as of the end of 2001 (11th Report, 2002).

3.1 REGULATORY AND PERMITTING REQUIREMENTS

The original mine plan and reclamation plan of 1990 (Viceroy Gold Corporation, 1990) had stipulations as Conditions of Approval by County and a Record of Decision by the BLM. These stipulations were amended during mine expansion in 1997 and 1998. The main stipulations related to revegetation during operations and reclamation were as follows (from 10th and 11th Reports, 2001 and 2002). Descriptions of the fulfillment of each of these requirements are in the sections as referenced in parentheses.

- Implement a revegetation research program consisting of:
  - A review of other arid lands revegetation programs
  - Research methodology development (see Sections 4.2, 8.0, and 9.0)
  - Determination of revegetation success using plant density and diversity measures (see Section 11.0)
  - Stockpiles of available topsoil (see Section 6.0)
  - Identification of dominant species for revegetation and salvage of individual plants for transplanting (see Sections 4.2, 5.0, 7.0, and 8.0)
  - Establishment of a nursery and greenhouse for testing plant species for their revegetation potential and development of a seed collection and storage program (see Sections 4.0 and 7.0)
  - A monitoring program (see Section 11.0)
- Establish a Revegetation Review Committee that meets annually (see Section 3.3)
- Fence the mine to exclude livestock (see Section 8.8.5)
- Submit annual revegetation reports (see Section 12.0)
- Provide baseline vegetation measurements (including onsite desert grasslands recovery) (see Section 9.1)
- Comply with all requirements of the CMM reclamation plan (Viceroy Gold Corporation, 1990), including achieving density and diversity requirements (see Section 3.2), distribution of stockpiled soil (see Sections 6.0, 8.3.2, 8.4, 8.6, 8.10, 8.11, 8.12, and 9.11), and use of soil amendments
- Revegetate third party disturbance

- Achieve bond release after 10 years of monitoring

3.2 Revegetation Requirements

Permit requirements and bond release specifications stipulate that CMM reclamation reestablish 15% of native plant diversity and 21% of native plant density ten years following mine closure (8th Report, 1999). These percentages were originally to be based on baseline vegetation data (see Section 9.1).

3.3 Revegetation Review Committee

The CMM Revegetation Review Committee (RRC), a group of individuals representing federal, state, and local government; ecological and reclamation specialists; the environmental community; and industry, was established on September 27, 1990. At its inception the RRC included arid lands vegetation and revegetation experts, a geologist/hydrologist, and representatives from the environmental community, County, BLM, the State of California Department of Conservation (Division of Mines and Geology), and Viceroy Gold Corporation (Viceroy). Members of academia also participated in RRC proceedings on an *ex officio* basis (1st Report, 1992).

The RRC was formed in response to two years of discussion among Viceroy, the BLM, the State of California, the County, the Natural Resources Defense Council, the Sierra Club Legal Defense Fund, the Wilderness Society, Desert Survivors, the California Wilderness Coalition, the Desert Protection Council, and Citizens for Mojave National Park, all of whom agreed on the need for information concerning revegetation of semi-arid desert lands. The purpose of the RRC as initially stated was to review each annual revegetation report from CMM and to make recommendations to Viceroy, the County, and BLM regarding the effectiveness of the CMM revegetation program (1st Report, 1992). Table 1 describes all meetings of the RRC as reported in the Annual Revegetation Reports.

3.4 Staff Revegetation Ecologists

In August of 1992 Dr. Raymond Franson was hired as the primary revegetation ecologist for CMM. Dr. Franson's specified responsibilities included plant salvage, revegetation of mined land, nursery management, plant production in greenhouses and nurseries, seed collection, revegetation research in cooperation with David Bainbridge of San Diego State University (SDSU), and submission of annual revegetation reports (1st Report, 1992).

Table 1. All Revegetation Review Committee meetings reported for Castle Mountain Mine.

Date	Location	Comments	Reference
May 13, 1991	Walking Box Ranch (CMM)	Meeting minutes available in 1st Report (1992).	1st Report, 1992
December 15-16, 1991	Joshua Tree National Monument		
March 29-30, 1992		"Committee Recommendations Regarding Revegetation Activities and Research Plan" [draft] produced October 5. Meeting minutes and report available in 2nd Report (1993).	2nd Report, 1993
March 27-28, 1993	CMM	Toured the nurseries and three of the growth media piles. Meeting minutes available separately.	3rd Report, 1994
March 31-April 1	Walking Box Ranch (CMM)	To review 3rd Report (1994). Minutes available separately.	4th Report, 1995
September 24, 1994	San Francisco	To review Rick Everett's statistical analysis of vegetation data (see Section 9.1).	
March 27-28, 1995	Walking Box Ranch (CMM)	To review Annual Revegetation Report.	5th Report, 1996

On February 1, 1994, a greenhouse and nursery technician was added to the CMM revegetation staff. On March 16, 1994, an intern from the Environmental Studies Program at the University of Nevada-Las Vegas (UNLV) began work in the greenhouse and nursery. These individuals also contributed to "devegetation" and revegetation activities at CMM (4th Report, 1995).

In March of 1996 a second full-time greenhouse technician began at CMM. This brought the revegetation staff to a total of three full-time individuals (6th Report, 1997). Dr. Franson resigned from CMM in March 1997 and was replaced in July 1997 by Dr. Michael Eichelberger. Following this change, all research projects were reevaluated in the context of CMM reclamation goals (7th Report, 1998).

3.5 San Diego State University Revegetation Research Grant

David Bainbridge, a research associate at San Diego State University (SDSU), was awarded a grant to research revegetation techniques at CMM. The work officially commenced on September 21, 1992 (2nd Report, 1993), the grant was renewed in October 1993 (3rd Report, 1994), and continued through 1995 (5th Report, 1996). Dr. Bainbridge resigned in October 1995. In June 1996, SDSU delivered all outstanding data from three years of his grant work, including soil samples and their partial analysis.

Despite prior distinctions between SDSU research and that initiated and/or conducted exclusively by CMM personnel, as of 1994 these distinctions were not recognized by either institution and collaboration was entirely mutual (4^{th} Report, 1995). Interaction between SDSU and CMM was fully inclusive from experimental design to field work, analysis, and interpretation. For this reason, unless otherwise noted, the SDSU Revegetation Research Grant supported all reclamation and revegetation activities at CMM at least in part, and SDSU personnel participated accordingly.

4.0 NURSERY AND GREENHOUSE OPERATIONS

Early in the CMM reclamation and revegetation program a total of four plant nurseries (or salvaged plant holding areas, SPHAs) were established and three were maintained throughout the life of the mine. The original four nurseries were the north nursery, the south nursery, the east nursery, and the overburden nursery (5th Report, 1996). Between 1991 and 1994 all salvaged plants (Section 5.0) were transported to either the north or south nursery. The north nursery was intended to serve reclamation needs of the pit and overburden areas, while the south nursery was intended for that of the leach pad areas.

Greenhouse construction commenced in December 1992 (2nd Report, 1993). The greenhouse structure was finished in 1994. Full-scale, intensive plant growth was underway in the greenhouse by May of 1994 (4th Report, 1995). During its activity the greenhouse had as many as 17,000 plants being grown in the greenhouse and the shaded areas (9th Report, 2000).

4.1 GREENHOUSE AND NURSERY BUILDINGS, INFRASTRUCTURE, AND EQUIPMENT

The following subsections describe the physical buildings that supported greenhouse and nursery operations, infrastructural components such as soil moisture sensors and irrigation systems, and other equipment procured over the course of active greenhouse/nursery research such as vehicles, a weather station, and a generator.

4.1.1 Buildings and Related Structures

As stated above, construction of the 5700-ft^2 greenhouse was initiated in December 1992 (2nd Report, 1993) and was completed in 1994 (4th Report, 1995). Five 24 × 220-foot shade structures were designed in both north and south nurseries with the expectation that the shade provided would reduce transplant mortality. Fifty percent shade cloth was acquired in 1992 (1st and 2nd Reports, 1992 and 1993) and the shade structures were in use by 1995 (5th Report, 1996).[1]

Construction on a straw bale seed storage building started in December of 1994 and was completed on September 21, 1995 (4th and 5th Reports, 1995 and 1996). The 32 × 23-foot building, located next to the greenhouse, was built out of three-string rice straw bales. Within the building, one 19 × 9-foot room was designated for seed storage and the remainder of the space for a

[1] The 5th Annual Revegetation Report (1996) gave installation and removal dates of May 3-Nov 1, 1995, and also stated that "the shade structure" was removed in early January and reinstalled on June 30th, 1995. It is unclear whether these differing dates are specific to differing shade structures.

tractor and other equipment (4th Report, 1995). Upon completion, the first of a growing seed collection was placed in the seed storage room, which maintained a constant temperature of approximately 65°F without supplementary heat or cooling (5th Report, 1996).

The east and overburden nurseries were constructed in 1995. The site for the east nursery was selected in the hopes that it would be more hospitable to barrel cacti than the north or south nurseries. The east nursery was situated on a steep hillside facing southwest and was subject to erosion from rain in the summer of 1995; transplanted barrel cacti suffered 35% mortality between June and October of 1995 (5th Report, 1996).

The overburden nursery was a 50' × 170' area on the South Overburden pile, previously ripped and adjacent to growth media pile 3A. This was also intended for barrel cactus (5th Report, 1996). In 1998 two 8 × 10-foot aluminum storage buildings on 2 × 6 reinforced wooden floors were assembled to store potting materials and tools. The storage sheds included a wooden bin to contain pumice for the potting mix and a holding area was constructed to store pots.

4.1.2 Greenhouse and Nursery Infrastructure

In the summer of 1993, all nursery plants were watered weekly. In August 1993, to better indicate when plants needed watering, gypsum block soil moisture sensors were installed at 8- and 16-inch depths in two rows each of Joshua tree, Mojave yucca, banana yucca, and barrel cactus and Joshua tree boxes at each nursery (3rd and 4th Reports, 1994 and 1995). Initial readings in August and September 1993 indicated that Joshua trees need irrigation more frequently than the other two yucca species (banana and Mojave) at the nurseries (3rd Report, 1994). Watering for the 1994 growing season began on May 26 (4th Report, 1995). The 5th Report (1996) noted that, following the extended drought, the moisture sensors performed poorly and did not register properly in the spring of 1995, despite heavy winter rains. Use of the sensors was discontinued on May 16, 1995 (5th Report, 1996).

To address rodent damage at the nurseries (see Section 4.3 below), in June of 1993 a new irrigation system with aboveground drip lines and inline emitters was installed at both nurseries. With the exception of button drip emitters used to irrigate boxed plants (3rd Report, 1994) and one chewed drip line near a spigot (4th Report, 1995), the systems appeared resistant to rodent damage. During the spring of 1994 the original water line to the south nursery was removed and a new one with improved water pressure installed. Irrigation systems were shut down for the fall/winter in September 1994 since the soil moisture meter would not function below 45°F (4th Report, 1995). In May of 1995 a new water line from a large water tank at the north nursery was connected to the greenhouse to serve as a backup water supply (5th Report, 1996). A new drip line irrigation system was constructed in 1997 (7th Report, 1998).

4.1.3 **Greenhouse and Nursery Equipment**

In 1993 a variety of equipment was acquired for the revegetation program, including a tractor, 16-foot trailer, microscope, storage buildings for both nursery tanks, a 250-gallon water tank, composters, and a weather station. The weather station, located south of the administration building, was equipped with a temperature sensor, anemometer, barometer, and soil sensors. The weather station began collecting data on March 17, 1993 (3rd Report, 1994).

Year-round daytime temperatures in the greenhouse were set to 90°F (explained below in Section 4.2). A swamp cooler kept greenhouse temperatures lowered to this temperature during the growing season. Exceptions occurred during several daytime power losses when internal greenhouse temperatures rose as fast as 1°F/min. On July 4, 1994, 144 seedlings died as a result of inordinately high temperatures. A 125-kw automated backup generator was installed later that month. Conversely, during the cooler seasons the greenhouse heaters could not maintain the required internal temperature of 90°F. In October 1994, the shade cloth inside the roof was removed for the winter, but on some winter days the greenhouse temperature did register below 90°F (4th Report, 1995).

In 1994, new greenhouse equipment included forty-two 8' × 4' × 3' metal greenhouse benches, an improved water line to the south nursery (mentioned in Section 4.1.2), a vehicle (4-door, 4WD Suzuki Sidekick), a laboratory bench for the 15 × 36-foot headhouse/laboratory, an electronic balance, a miniature 12-volt pump for the Kolapsatank to aid watering at remote revegetation sites, the 125-kw backup power generator discussed above, a 35mm SLR camera, a backhoe attachment for the tractor, a chipper/shredder, and a woodburner for labeling wooden stakes. In addition, the revegetation ecologist acquired an e-mail address through UNLV (4th report, 1995).

In May 1995 a shade canopy constructed of 50% shade cloth was built over a plant propagation bench to provide additional shade for sensitive small plants. These species generally establish under a larger plant in natural conditions. In September another shade canopy and a mist system was added to another propagation bench (5th Report, 1996).

In 1995 the greenhouse experienced problems with three of its four heaters, the circulation fans, the louver motors, the swamp cooler, the water line, and the backup generator. Also during this year a record-keeping system was initiated in the hopes of standardizing all records kept by various personnel. New equipment added in 1995 included a backhoe attachment for the tractor,[2] wheel weights for the rear wheels of the tractor to make it more stable in revegetation areas, a portable 4hipper/shredder for plant debris, a backup water line to the greenhouse from the water tank in the north nursery, 20 additional metal benches for the greenhouse (for a total of 63 benches), and a rain gauge outside of the greenhouse (5th Report, 1996).

A refrigerator was added to the laboratory/headhouse in 1996 for VAM storage (6th Report, 1997, see Section 8.5 for VAM research). In order to emphasize the full-time commitment to greenhouse operations and maintenance, the 6th Report (1997) provided a table of the mechanical problems encountered in 1997 alone. A total of fourteen mechanical issues were addressed in eight months of that particular calendar year (Table 18, 6th Report, 1997).

In 1998 CMM constructed a raised planter bed for *Yucca* species between the first row of the North nursery and the west side of the greenhouse parking area. The bed was filled with sieved growth media from the leach pad area. In addition, CMM procured 35 new benches with 24" legs for the shade cloth area, creating 1120 ft^2 of bench space in the shade cloth area. The original benches under the shade cloth area were moved to the greenhouse, increasing the number of benches in the greenhouse to 60 and the area available for propagation to 1920 ft^2. New equipment procured in 1998 included a pressure cooker and an electric stovetop, the combination of which to serve as an autoclave; a pH meter; a magnetic stirrer; assorted glassware; storage cabinets; a water potential meter; and literature (8th Report, 1999).

In 1999, a laminar flow hood was constructed and a pressure cooker to be used as an autoclave[3] was purchased for the greenhouse (9th Report, 2000).

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[2] A backhoe attachment for the tractor was also mentioned as a new acquisition for 1994; it is unclear whether two backhoe attachments were acquired in two years or if there was confusion over the year that the attachment was in fact acquired.

[3] A pressure cooker to be used as an autoclave was also stated to have been acquired in 1998 (8th Report, 1999).

4.2 PLANT PROPAGATION

Large-scale growth operations inside the greenhouse began in May 1994. Year-round daytime temperatures in the greenhouse were set to 90°F, the approximate temperature a few inches aboveground on an average summer day at CMM (see further comments on the thermostat setting in Section 4.1.3). By 1996, plant propagation procedures, summarized below, were fairly well-established in the greenhouse.

As of December of 1994, the greenhouse was growing plants from 32 species native to CMM in 3,130 containers, and 435 seedlings were being prepared for potting (4th Report, 1995). By December 1995 the greenhouse housed 5,494 containers each holding one or more plant individuals representing 52 native species (5th Report, 1996). In 1996 fourteen species were propagated from seed and/or cuttings in the greenhouse, nine of them for the first time, all propagules were collected within twenty miles of CMM. By the end of 1996 the greenhouse held 6,175 containers representing 50 genera and 66 species of native plants (6th Report, 1997).

By the end of 1997 a total of 8,293 specimens were being grown in the greenhouse and one of the shaded areas. Of these plants, 4,059 individuals representing six species – hedgehog cactus, beehive cactus, barrel cactus, box thorn, Mojave sage, and Indian ricegrass – were propagated for the first time (7th Report, 1998). In 1998 4,660 plants were propagated from seed or cuttings (8th Report, 1999), and by the end of 1999, 12,928 plants were growing in the greenhouse. This figure does not include the 3,000 plants raised for public donation or the 996 transplanted from the shade structure to Revegetation Area 8A on the South Overburden (see Section 8.8.3; 9th Report, 2000).

Questions addressed by greenhouse researchers included (4th Report, 1995):

- Which containers are best for greenhouse propagation?
- Which containers are best for outplanting?
- Which potting soil mix or mixes are best for greenhouse propagation?
- Which potting soil mix or mixes are best for outplanting?
- Which germination method or methods are best for different native Mojave Desert species?

In 1998, all plants were transplanted to a new inorganic growth medium. Previously the growth medium for all CMM greenhouse-grown plants was 100% calcined clay (oil-absorbent kitty litter), a porous, low-nutrient, low-organic medium that theoretically encourages root establishment once plants are transplanted to the field (6th and 7th Reports, 1997 and 1998). Growing plants in the calcined clay produced plants with low vigor, even if they were fertilized. The mix introduced in 1998 was comprised of 2 parts calcined clay, 1 part vermiculite, and 1 part pumice (8th Report, 1999).

In 1999, greenhouse personnel successfully propagated nineteen species of native plants from seed and two species – golden cholla and Mojave prickly pear – from cuttings. Unsuccessful germination trials were attempted on Utah juniper seeds (9th Report, 2000). See more details on germination are provided below.

4.2.1 **Seed Germination**

General procedures for seed germination in the laboratory/headhouse were as follows (5th Report, 1996):

- Seeds were surface-sterilized with isopropyl alcohol for at least two weeks to prevent mold growth. Surface-sterilization decreases germination of "some seeds".
- Germination occurred in sterilized wicking dishes, i.e., glass baking dishes lined with a paper towel, covered with clear plastic.
- Seed was watered by tilting the wicking dish, adding distilled water at the lower end of the dish, and allowing the paper towel to wick it towards the seed. This method allowed the seed to absorb water without over-saturation or desiccation.
- Germination occurred under grow lights at approximately 70°F.

Table 2 outlines additional germination treatments that were specific to species, such as scarification (e.g., blackbush), leaching (e.g., creosote bush), and hormone additions (e.g., box thorn). Between December of 1994 and July of 1995, sixteen species of plant seed were germinated. These were blackbush, creosote bush, Joshua tree, Mojave yucca, fourwing saltbush, burrobush, box thorn, Apache plume (*Fallugia paradoxa*), beardtongue (*Penstemon bicolor*), green (Virgin river) encelia, desert willow, cotton (felt) thorn, hedgehog cactus, pancake prickly-pear, beavertail cactus, and Indian ricegrass (5th Report, 1996).

Table 2. Methodologies used for seed germination and resulting germination rates, CMM, 1996-1999.

See the 8th Report (1999), Table 5, for seed ages in 1998 trials. See Appendices A and B for Latin nomenclature if not specified here. All information is from the 6th, 7th, 8th, and 9th Reports (1997, 1998, 1999, and 2000).

Species	Date	Methodologies	Percent germination
Antelope bush (*Purshia glandulosa*)	1998	60-d stratification at 40°C. Sown directly in Metro-Mix 200.	15
Banana yucca	Sep 1997	200 seeds placed in wicking tray. Mouse "consumed a large portion."	n/s
	1998	No pretreatment. Seeds placed on moist paper towels in covered Pyrex dish. Germinated seeds sown in Metro-Mix 200.	79
Barrel cactus	Jan 1997	1000 seeds sown in mixture of commercial potting soil and #30 silica sand (proportions unspec.) in shallow plastic pot. Pot watered, covered with clear plastic bag, and placed beneath grow light in headhouse.	68
Beehive cactus	Jan 1997	500 seeds treated as barrel cactus (above).	41
Blackbush	1996	Not scarified; soaked in a mild chlorine solution to sterilize the seed coat	8
	1998	See discussion below.	
Boxthorn (*Lycium andersonii*)	Jul 1997	196 seeds sown directly into 3:2:1* mix.	2
Boxthorn (*L. cooperi*)	Jul 1997	196 seeds sown directly into 3:2:1 mix.	0
Brickellbush	1998	No pretreatment. Sown directly into Metro-Mix 200.	86
California buckwheat	Aug 1996	Batch 1: seed coat removed. Batch 2: wings removed but seed coat left on. All seeds sown directly into 3:2:1 mix.	11, 1
	1998	Outer seed coat removed. Sown directly in Metro-Mix 200.	23
Cheesebush	Jun, Sep 1996	Seed coat ground and wings knocked off. Jun: seeds sown in peat-based mix in multi-celled germinating trays. Sep: seeds sown in 3:2:1 mix.	26, 87
Cotton thorn	May 1996	Batch 1: Pappus removed. Batch 2: pappus intact. All placed on wicking trays.	91, 78
	Jan 1997	Pappus removed from 196 seeds, which were directly sown into 3:2:1 mix.	92
	1998	24 h leaching	12
Coyote melon	Sep 1996	Seeds placed on wicking tray.	22
Creosote bush	May, Aug 1996	Leached in a nylon stocking by pumping water through stocking into 3.5-gal bucket. Rinse water reused. Water changed several times in the first few days as seed leachate built up. All seedlings planted in calcined material. *If creosote bush seedlings are watered from above, they lose volatile oils and die.* Alternatives are to water seedlings from the side (methods n/s), or "wick-watering," i.e., dipping seedling container racks in water up to 1" from top of seedling container. Wick-watering method is effective even with the use of a calcined growing medium.	48, 52
	Jan 1997	2 batches of 300 seeds each treated as in 1996.	50, 47
	1998	Leached w/ H_2O for up to 5 d; germinated seeds removed daily. Sown directly in Metro-Mix 200.	45, 32

Species	Date	Methodologies	Percent germination
Desert almond	1998	Outer seed coat removed, 50-d. stratification at 5°C. Sown directly in Metro-Mix 200.	66, 77
Desert needlegrass	Jun 1997	No pre-treatment. Seeds sown directly into 3:2:1 mix.	70
Fourwing saltbush	1996	Seeds "ground," wings knocked off, surface-sterilized with chlorine bleach. Placed in a single wicking tray in headhouse. Two wetting/drying cycles.	3
	1998	Continuous dark at 15°C	18
Galleta grass	Jan, Jun 1997	196 seeds sown directly into 3:2:1 mix.	56, 78
Goldenbush (*E. cooperi*)	1998	No pretreatment. Sown directly in Metro-Mix 200.	1
Goldenbush (*E. cuneata*)	1998	No pretreatment. Sown directly in Metro-Mix 200.	54
Goldenhead	1998	Outer seed coat removed. Sown directly in Metro-Mix 200.	78
Hedgehog cactus	Jan 1997	500 seeds treated as barrel cactus (above).	52
Hop-sage	May 1996	Seeds removed from papery fruit sac, placed on wicking tray.	72
Indian ricegrass	1997	No pre-treatment. Seeds sown in 3:2:1 mix.	<1
Interior goldenbush	1998	No pretreatment. Sown directly in Metro-Mix 200.	88, 11
Joshua tree	1997	8000 seeds pre-germinated in wicking trays and then planted in organic potting mix.	n/s
Mojave aster	Feb 1996	Seeds soaked in bleach, placed on wicking tray.	88
Mojave sage	Dec 1997	196 seeds sown directly into Scott's Metro-Mix 200 Growing Medium.	13
Mormon tea	Feb, Aug, Sep 1996	Feb & Aug: seeds surface-sterilized in bleach and placed in wicking tray in headhouse. Sept: no pre-treatment; seeds sown in 3:2:1 mix, placed in greenhouse.	33, 21, 52
	May 1997	588 seeds sown directly into 3:2:1 mix.	18
Pima rhatany	1998	Leached w/ H_2O for 24 h. Sown directly in Metro-Mix 200.	71
Salvia dorrii	1998	No pretreatment. Sown directly in Metro-Mix 200.	31
Salvia mojavensis	1998	No pretreatment. Sown directly in Metro-Mix 200.	28
Shrubby encelia	1998	No pretreatment. Sown directly in Metro-Mix 200.	75
Shrub live oak (*Quercus turbinella*)	1998	No pretreatment. Sown directly in Metro-Mix 200.	57
Sticky snakeweed	1998	Batch 1: no pretreatment, sown directly in Metro-Mix 200. Batch 2: 24 h leaching. Batch 3: alternating day-night temperature and photoperiod (details unspec.)	(1) 59, 37; (2) 12; (3) 16
Turpentine-brush	1998	No pretreatment. Sown directly in Metro-Mix 200.	73, 51, 31
Utah juniper	Feb 1996	Mixed w/ moist vermiculite, placed in plastic bag and stratified for 3 mo. either at room temperature (Batch 1) or in a refrigerator (Batch 2). Seeds rinsed and placed on wicking tray.	2, 3

Species	Date	Methodologies	Percent germination
	1999	200 seeds scarified in 17.5N H_2SO_4 for 2 h, stratified @ 2°C for 8 wks and brought to ambient temp for 8 wks.	0
Viguiera	1998	No pretreatment. Sown directly in Metro-Mix 200.	79
Winterfat	1998	Outer seed coat removed. Sown directly in Metro-Mix 200.	24, 86, 88

n/s ≡ not specified

* 3 parts calcined clay: 2 parts medium-grade vermiculite : 1 part standard organic potting mix (7th Report, 1998)

In 1997, CMM changed its primary seedling growth medium from the 3:2:1 mixture to Scott's Metro-Mix 200 Growing Medium, a commercial organic soil mix that contained vermiculite, peat moss, perlite, and sand. Seedlings in the 3:2:1 mix did not grow as rapidly or vigorously as did those in a more conventional growth medium, probably due to the coarse texture of the 3:2:1 mixture, which has little water retention and frequently presented desiccation problems. At the time of the 7th Report (1998) there was no evidence that seedlings grown in this mix experienced transplant shock when transferred to a calcined clay mixture (see discussion on calcined material in Section 4.2; 7th Report, 1998).

In 1998 it was observed that germination failures could be due to seed parasitism, aborted seed development, seed immaturity, and seed dormancy. Dormancy can be released by several means, such as with the use of particular light regimes. Other methods were tested as follows:

- Stratification (cold incubation) of blackbush seed for 60 days (temperature unspecified) increased average germination rates by 75.5%. All stratification trials were carried out on agar plates (Petri dishes); results were promising enough that propagation procedures thenceforth called for the use of agar plates for seed stratification.
- Seed coat scarification with 30% hydrogen peroxide (H_2O_2) for two hours increased blackbush seed germination by an average of 46.5%. Scarification with the use of a solution of 17.5 N sulfuric acid (H_2SO_4) did not significantly increase germination rates. The H_2SO_4 treatment, however, may have stimulated the germination of fungal spores endemic to the seed, as several species of mold were observed on the seeds following the acid treatment.
- Leaching of creosote bush seeds with distilled water (see methods in Table 2) resulted in significantly higher germination (data unspecific), presumably by removing germination inhibitors (8th Report, 1999).

Germination experiments in 1998 indicated that agar plates (Petri dishes) supplemented with Hoagland's nutrient solution were an ideal replacement to conventional potting mixes for cactus seed germination. Sealing the plates with Parafilm® after sowing maintained humidity and prevented desiccation; however, it also promoted fungal growth. To prevent fungal spores carried on cactus seeds from germinating, seeds were pretreated with Captan® fungicide. After germination and when large enough, seedlings were then be cut out of the agar with roots intact and transplanted to an organic medium for further growth (8th Report, 1999).

The nineteen species germinated in 1999 were antelope bush (*P. tridentata*), Apache plume, beehive cactus, black-stem, box thorn, catclaw, cheesebush, hedgehog cactus, hop-sage, interior goldenbush, mesquite, Mojave yucca, pima rhatany, rubber rabbitbrush, sagebrush (*Artemisia tridentata*), salvia, skunkbrush (*Rhus trilobata*), Utah juniper, winterfat, and woolly bur-sage. Other than those of Utah juniper, seeds were bathed in Captan® fungicide, rinsed with water, and placed on agar plates containing Hoagland's solution. The plates were sealed and placed under a grow light until germination, at which point the seeds were transplanted to a commercial potting mix in containers. See Table 2 for 1999 experiments on Utah juniper (9th Report, 2000).

CMM personnel decided to propagate a large number of Mojave yucca in 1999 because of its high potential for successful transplanting. However, the timing of this decision was somewhat risky since reclamation procedures were scheduled to accelerate soon after. Therefore, the potting mix used for the yucca was mixed richer to encourage growth rates, with 3 parts Metro Mix 366-P to 1 part pumice. Five thousand seedlings were transplanted into this mix where growth did "appear to be accelerated" (9th Report, 2000).

4.2.2 **Propagation by Cuttings**

Plant propagation by cuttings was determined to have several advantages (6th Report, 1997):

1) Plants were be propagated without seed;
2) Multiple new plants were produced from one parent plant;
3) Plants were propagated without killing or removing the parent plant; and
4) Plant material was transferred from the field to the greenhouse without disturbing a plant root system.

With the exception of Coyote melon, which was grown in a peat mix, all plants were grown in calcined material. Like germination methods, those for propagation by cuttings were species-specific as described in Table 3 (6th Report, 1997).

Table 3. Methodologies used for plant propagation from cuttings and resulting rooting percentages, CMM, 1996-1998.
See Appendices A, B, or C for Latin nomenclature. All information is from the 6th, 7th, and 8th Reports (1997, 1998, and 1999).

Species	Date	Methodologies	Percent rooting
Blackbush	Jun 1996	196 cuttings taken from greenhouse-grown plants. Batch 1: dipped in a 0.1% indole butyric acid* (Hormex No. 1). Batch 2: in 0.3% solution of same (Hormex No. 3). Cuttings planted in medium-grade vermiculite, placed under 50% shade cloth on a mist bench, and received one minute of misting every daylight hour.	85, 61
Boxthorn (*Lycium andersonii*)	May 1997	196 cuttings from North nursery. Batch 1: Hormex No. 3. Batch 2: Hormex No. 8.	22, 28
Boxthorn (*L. cooperi*)	May 1997	Unspec. number of cuttings from North nursery. Two batches treated as *L. andersonii* above.	14, 6
Creosote bush	Jan 1996	12 cuttings taken from greenhouse plants, dipped in 0.8% indole 3 butyric acid (Hormex No. 8), planted in vermiculite, watered with distilled water, and placed under grow lights in the headhouse.	8†
Fourwing saltbush	May 1996	196 15-18 cm-long cuttings taken from ends of shoots growing on the CMM site. Leaves removed from base of each cutting. Batch 1: dipped in Hormex No. 3; Batch 2: dipped in Hormex No. 8. All planted in vermiculite. Containers were placed on the mist bench in the greenhouse.	57, 66
	Nov 1997	78 cuttings from plants propagated from seed, treated w/ Hormex No. 8, planted in medium-grade vermiculite.	17 (not final)
Golden cholla	Aug 1996	217 cuttings taken from north of greenhouse, cured for 2 weeks in greenhouse, potted in calcined material in 1-gal pots.	100
	1998	Cuttings healed for 2 wks. Planted directly in calcined clay.	100
Mojave prickly-pear	Aug 1996	170 cuttings taken near Hart cemetery, cured for 2 weeks in greenhouse, and potted in calcined material in 1-gal pots.	100
	1998	Cuttings healed for 2 wks. Planted directly in calcined clay.	100
Pima rhatany /purple heather	May, Aug 1996	May: 98 6-16 cm-long cuttings taken from ends of shoots in field, planted in vermiculite, and placed on mist bench. Aug: 196 cuttings taken from field. Batch 1 treated w/ Hormex No. 3, Batch 2 treated w/ Hormex No. 8.	1, 0, 6

* Indole butyric acid is a rooting hormone.
† This rate was considered successful; as it was the first attempt of three to successfully grow creosote bush from cuttings.

4.3 NURSERY AND GREENHOUSE PESTS

Populations of desert rodents such as packrats, mice, and ground squirrels were inordinately high inside the CMM nurseries during the 1992 growing season. The rodents chewed through the nursery irrigation system tubing to gain access to water. Because the “spaghetti lines” were attached to buried PVC pipes, each time a line was damaged the entire pipe required excavation for proper repair. Rabbits also presented a challenge as they penetrated the fence and ate cactus pads. At this time, managers determined that an alternative drip irrigation system should be considered and that live-trapping the rodents and rabbits would be the only effective means of control (2nd Report, 1993). A new drip irrigation system was installed in June of 1993 (see Section 4.1.2). This system appeared largely resistant to rodent damage (3rd Report, 1994).

The winter of 1992-1993 brought exceptional quantities of precipitation which was followed by a burst of vegetative growth. Cottontail rabbit populations expanded accordingly and placed high demand on the vegetation during the summer of 1993. In September of 1993 these "desert beaver" chewed the base of Joshua trees in the north nursery. Also during this season, rodents chewed drip emitters in boxed Joshua trees and the wires of soil moisture sensors (3rd Report, 1994).

In February of 1994, two dogs were placed in the north nursery to deter rodents and provide security at the greenhouse, which was in a remote location. Also in 1994, holes in and under fencing and around gates were closed, and packrat middens were removed from the nurseries. Shrubs growing in nursery rows were pruned. (4th Report, 1995).

Aphids and mealy bugs appeared on greenhouse plants in 1994, the latter on cacti. Starting in January 1995, "over-the-counter" pesticides were used for their control, but aphids increased nonetheless (4th Report, 1995). In April of 1995, ladybird beetles or "ladybugs," a natural predator of aphids and mealy bugs, were released in the greenhouse. The beetles completed one life cycle by May, did not maintain their original population numbers, and were insufficient to control the aphids and mealy bugs. Some plants were sprayed with malathion in the summer of 1995 (5th Report, 1996).

In 1996, watering of the south overburden nursery promoted the unwanted, prolific growth of the weed Russian thistle (*Salsola tragus*). Manual removal of the Russian thistle took an inordinate amount of labor and reinforced decisions to not utilize large-scale irrigation for CMM revegetation procedures. In the greenhouse, pests in 1996 included pack rats (which defoliated mesquite and catclaw); ants (whose populations appeared to be particularly exacerbated by the drought); white flies on Coyote melon plants; aphids; mealy bugs; spider mites; and scale insects. Only over-the-counter pesticides had been applied by end of 1996 (6th Report, 1997).

4.4 WETLAND DISPLAY

In March of 1996, the CMM revegetation ecologist established an artificial wetland as an educational opportunity for those touring the greenhouse facilities, few of whom were familiar with desert wetlands. The wetland supported cattail (*Typha* sp.), Goodding's black willow (*Salix gooddingii*), horsetail (*Equisetum* sp.), Alamo or Fremont cottonwood (*Populus fremontii*), mesquite (*Prosopis glandulosa*), and desert willow, all of which are native to the eastern Mojave Desert but not endemic to the CMM property. In addition, volunteer desert willow, globemallow, and tamarisk (*Tamarix* sp.) colonized the wetland. Tamarisk is an invasive species and was removed. The wetland was filled with water as needed and represented a drainage gradient ranging from saturated to ephemeral. Animals attracted to the wetland included quail and badger (6^{th} Report, 1997).

5.0 PLANT SALVAGE

Permitting stipulations and conditions of approval for mining by the BLM and County required certain plant species to be salvaged and placed into nurseries until they could be used mine site revegetation. Salvage was specified for at least 25% of barrel cacti and the three native yucca species (10th Report, 2001). Therefore, in accord with the Environmental Impact Statement/Environmental Impact Report (EIS/EIR; Viceroy, 1989), plant salvage from areas of disturbance at the CMM was an intensive part of the reclamation program.

Plant salvaging can be important to revegetation efforts for several reasons. First, salvaged plant material generally serves as a significant source of soil microflora and fauna, which are essential to healthy plant-soil dynamics. Second, salvaged plant material provides shelter and protection for seed and other nearby plants. Third, plant salvaging, if done properly, is cheaper than purchasing and transporting new plants of a similar size from a commercial nursery for transplanting (1st Report, 1992).

5.1 SALVAGE METHODS

All areas designated for plant salvage were surveyed in order to designate salvage classes for each plant based on its size. These classes were (1) too small to survive transplanting, (2) optimal (would survive transplanting and can be handled by one or two people), and (3) too big. Actual salvageability of a plant depends on more than size, however, as factors such as topography, site access, and subsurface conditions also required consideration (7th Report, 1998). The CMM salvage schedule is summarized in Table 4.

CMM plant salvaging activities commenced on March 23, 1991. This time of year was noted to be exceptionally difficult for ensuring transplant success. The areas first targeted for plant salvage were the mine access and exploration road north of Hart (revegetation road #4), leach pad, and pit areas. Wildlife biologists scouted for desert tortoises (*Gopherus agassizii*) and flagged salvageable vegetation. Orientation to the cardinal direction was noted for Joshua trees, Mojave yucca, banana yucca, barrel cactus, and “other species of cacti…sensitive to orientation in relation to the sun” so that their transplanted orientation would be consistent with their original orientation (1st Report, 1992).

Table 4. Plant species salvaged at CMM by date.
See Appendix A for Latin nomenclature.

Species	Number of plant individuals salvaged by date									
	Mar '91	**Nov '91-Jun '92**	**Dec '93-Jan '94**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2001**
Banana yucca	217	4		2	30	25	5	40	20	
Banana & Mojave yucca (not distinguished)										102
Barrel cactus	6278	82	27		755	611	965	299	257	1225
Beavertail cactus	116				71	2				
Beehive cactus	9				2	5				
Buckhorn/golden cholla	90									
Club/mat cholla	34		[clump]							
Clustered barrel (cottontop) cactus	456	2	3		22	34				
Creosote bush	5	9								
Hedgehog cactus	475	25			135	22			51	
Golden cholla						47				
Joshua tree	1569	300	125	132	297	307	205	345	98	305
Mojave prickly-pear	366	35			14				9	
Mojave yucca	964	67		12	33	142	73	72	52	
Nipple/Fish-hook cactus					26	4			5	
Pancake prickly-pear	46				71				2	
Silver cholla		7								
Other cacti						63				
Total individuals	**10,625**	**531**	**155+**	**146**	**1456**[4]	**1262**	**1248**	**756**	**494**	**1632**

For the 1991 salvage operations, a crew of 16 individuals removed the plants using either the tree spade or bare root method. Tree spades excavated large, mature trees and shrubs with the root system intact. With a survival rate of 95% or greater, tree spades were more effective than the bare root method; however, they were limited to slopes less than 15%, they took more time than the bare root method, and their operation was expensive at $125-400 per individual (1st Report, 1992). The bare root method was used on the majority of salvaged plants at CMM, executed with a bladed pick-axe (a Mattock) to remove bare root stock and excavate holes for

[4] This figure was calculated from the field data provided; however, the 5th Report (1996) stated this value to be 1439 individuals. The report later states that at least three blackbush were also salvaged from the area to be cleared for the Oro Bell haul road.

transplants. The root systems of several cactus species, excavated using the bare root method, were allowed to harden with their roots exposed for about one week before replanting (1st Report, 1992).

For transplanting to the nurseries, one of two planting methods were used, either the "posthole" or the "V-trench" method. The posthole method entailed the excavation of a hole large enough to contain the [trimmed] root system of a plant, which was dusted with sulfur to prevent airborne disease. First, the hole was moistened, then the plant positioned in the hole, and lastly, soil was filled in around the roots and tamped to secure the tree or shrub. For the V-trench method, a 12-14"-deep trench was dug with a backhoe and the plant roots were suspended above the trench with the plant on its side on the ground. Over an unspecified period of time, the crown of the plant was tilted upward while the roots descended, and soil was gradually placed around the root system. The V-trench system, which was used partly in the north nursery and entirely in the south nursery, was thought to reduce root trauma. Except for barrel cactus, preliminary observations in September and December of 1991 indicate that the V-trench method resulted in lower plant mortality than the posthole method (1st Report, 1992).

Transplanted Joshua trees, banana yucca, and Mojave yucca received base watering once a week following the 1991 salvaging operations. "Crowns," presumably of all transplants, also received water once a week. Joshua trees responded more favorably to crown than basal irrigation (1st Report, 1992).

Calculations in the 3rd Report (1994) indicate that the CMM salvage program had exceeded the 25% salvage goal as stated in the EIS/EIR (Viceroy 1989).

In 1995, 1456 plants were salvaged from the Oro Belle haul road (7 species), the leach pad expansion area (8 species), the south overburden expansion area (5 species; this was the area below the 1995 overburden pile that was previously salvaged in 1992), and the Oro Belle and Jumbo pits (or hills; 4 and 3 species, respectively). All salvaged plants went to one of the four nurseries or to revegetation areas (5th Report, 1996).

Salvage operations on Jumbo Hill were completed in 1996. Plants were also salved from new pits, expansion of the leach pad, exploration and well roads (Drill roads A [near the north nursery], E [Dana's Dome], L, M, N, and Razorback), and a new helipad (for emergency medical helicopters). Parameters for what were considered salvageable size classes were intensively reevaluated in 1996, as Joshua trees both larger and smaller, and Banana yuccas and barrel cacti smaller, than the stated salvageable size classes had been successfully salvaged (6th Report, 1997). In 1998, the Milma Patent Area (North Overburden), the east side of the North Overburden (Waste Dump), and the expansion area on the leach pad were salvaged. All plants from these areas were transplanted to the revegetation area on the South Overburden (8th Report, 1999).

There were two areas from which plants were salvaged in 1999. The first was the right of way for an exploration drill road traversing the north side of the west haul road leading to the Oro Belle Pit. Six barrel cacti and three Joshua trees were salvaged from this area. The second salvage area was between the Jumbo Pit and the Hart Tunnel for the Oro Belle Pit expansion and provided 485 plants (Table 4). All plants were removed with the bare-root method. The larger yuccas were directly transplanted to Area 9 on the South Overburden, while the larger barrel cacti were transplanted to the drill roads adjacent to Area 8A, also on the South Overburden (see Section 8.8.3; 9th Report, 2000).

5.2 DONATION OF SALVAGED PLANTS TO OUTSIDE GROUPS

In October 1990, the BLM opened selected CMM areas to mining and reclamation groups, scientific organizations, botanical societies, commercial nurseries, and the general public for plant harvesting and sale. The areas available for plant harvest were those slated for intensive disturbance such as pits and leach pads (1st Report, 1992).

- In 1995 a number of groups from the public sector salvaged plants from areas scheduled for disturbance. The purposes of these salvage operations were commercial: for the display gardens of the Las Vegas Valley Water District (253 cacti), for the Santa Clara, Utah, arboretum (2 barrel cacti), and for the Santa Clara, Utah, elementary school (6 cacti; 5th Report, 1996).
- In 1996 the Lake Mead National Recreation Area, the University of Nevada – Las Vegas (UNLV), and commercial and private entities salvaged 350 plants from CMM. All plants salvaged by non-mine groups acquired plants outside the mine's salvageable size classes. Sixty-seven plants from the greenhouse, all grown from seed except for 27 cacti, were donated to UNLV, Friends of the Mojave Road, and a private party (6th Report, 1997).
- In 1997 the Chino Basin Water Conservation District salvaged 65 plants representing 8 species, and the BLM and Friends of the Mojave Road salvaged over 66 plants representing 15 species. All of these salvaged plants in 1997 were taken from areas planned for disturbance

or from greenhouse propagation. Also, Esparza's Trees and Plants received permission to collect 51 Joshua trees outside of the CMM salvageable size class. None of these Joshua trees were of a size that could have been moved by CMM personnel (7th Report, 1998).

5.3 SALVAGED PLANT HEALTH AND SURVIVAL IN NURSERIES

Results of salvaged plant surveys are summarized in Table 5. Results from the first survey indicate that mortality was the highest at 22% for Mojave yucca; conversely, Mojave prickly-pear, pancake prickly-pear, and creosote bush experienced 0% mortality (2nd Report, 1993). The 3rd Report (1994) singled out Joshua trees as particularly hardy transplants, although most of the other species outperformed them both in terms of survival and health status (i.e., excellent vs. poor).

Table 5. Summary of salvaged plant health assessment in the nurseries.
All four (the north, south, east, and South Overburden) nurseries were surveyed. Terminology describing plant condition was changed beginning with the 1997 survey.

Survey year	No. species	No. individuals	Health		
			% Excellent	% Poor	% Dead
1992	13	5,109	75	16	9
June 1993	8	7,941	68	18	14
Sept 1994*	8	8,482	63	7	30
Oct-Nov 1995	8	9,661	60	5	35
Oct-Nov 1996†	8	10,558	60	4	37
			% Good	% Fair	% Dead
1997	8	9618	58	1	41
1998	8	10,099	57	1	42

* The 5th Report (1996) amended the 1994 nursery plant survey with the observation that several individuals rated as dead later revived. The data in the table reflect that as originally reported in each revegetation report.
† survey performed by less experienced personnel

Observations in 1995 indicated that planting Joshua trees deeper than they originally grew could have contributed to high death rates of this species. Furthermore, recently planted Joshua trees were vulnerable to wind-throw until they established an extensive root system. For this reason transplanted Joshua trees required staking (5th Report, 1996). In 1998 vegetation ecologists deemed that, over the course of seven years, mortality of all salvaged plants was too high and probably due to bare-root techniques (see Section 11.1; 8th Report, 1999).

See also Section 9.4 for a summary of formal research on salvaged plant health.

6.0 SOIL ("GROWTH MEDIA") STOCKPILES

The stockpiling of soil or "growth media" was a stated priority for revegetation at CMM (see Section 3.1). Natural soil contains organic matter, viable seed, and microflora and fauna that improve soil fertility and productivity. The primary areas from which soil was stockpiled at CMM were those containing unsalvageable vegetation and its surrounding soil, delineated by the underlying caliche layer (1st Report, 1992).

Two types of equipment were compared for growth media collection. A "continuous miner" is used primarily for the mining of tabular surface deposits such as coal or phosphate ore. A "hydro-axe brush cutter" mulches vegetative biomass as deep as eight inches. Due to its greater ease of use, the hydro-axe proved superior to the continuous miner (1st Report, 1992).

The CMM reclamation plan (Viceroy Gold Corporation, 1990) predicted that the volume of salvaged and stockpiled soil would be 1,114 yd^3/disturbed acre. As of January 1995, CMM had salvaged 989 yd^3/disturbed acre (4th Report, 1995), a difference of 11%.[5] A summary of growth media stockpiles, the dates of their establishment, and volume is in Table 6. See Section 9.2 for a summary of formal research evaluating the quality of soil stockpiles at CMM.

Table 6. Growth media stockpiles.
A map of the stockpiles is in the 1st Annual Revegetation Report (1992).

Stockpile	Location	Date est.	Volume (cubic yards)	Seeded?
1A	W. of Lesley Ann Pit	Nov 1991	33,000	No
1B	S. of Lesley Ann Pit	July 1991	140,00	Yes
1C	W. of S. Overburden site	Dec 1991	30,000	Yes
1D	S. of heap leach pad area	Dec 1991	35,000	No
1E	S. of heap leach pad area	Dec 1991	15,000	Yes
SPHA	SW corner of S. nursery		350	No
2A	N. of S. overburden site	June 1992	36,700	No
2B	SW of heap leach pad	July 1992	44,000	No
3A	NW of 2A	May 1993	43,975	No
4A	Middle of S. overburden pile	Jan 1994	27,500	
4B (formerly 3B)	NW of 2B	Aug 1993, Jan 1994, Apr 1994	90,000 (incl. 5,000 from 3B)	No
5A	NW of and connected to 4B	May 1995	95,600	No
5B	S of and adjacent to 1A	Jun 1995	410	No

[5] The 4th Report (1995) misquoted the CMM reclamation plan (Viceroy Gold Corporation, 1990) as stating that the volume of stockpiled soil would be 1,014 yd^3/disturbed acre, and as a result, miscalculated the difference between actual and predicted volumes as that of only 2.4%.

Other observations and activities include:

- In 1995 growth media stockpile demonstrated its potential as a seed bank when California poppies germinated, bloomed, and set seed (5th Report, 1996).
- In addition to the edges of the mine road, some of the soil stockpiles were seeded in 1992 (stockpiles and month[s] unspecified). As of January 1993, this seeding had shown "little success" (2nd Report, 1993).
- As of January 1994, all apricot mallow and fourwing saltbush growing on soil stockpile 1B (Table 6) had been grazed to less than three inches in height (3rd Report, 1994).
- On January 19, 1994, stockpiled soil from pile 1A (Table 6) was turned into the top 2-3 feet of the middle bench of the South Clay Pit Reclamation Area with the use of a ripper. The growth media had been transferred to this spot in December of 1993. No plant propagules, e.g., seed, tubers, or rhizomes, were incorporated (4th Report, 1995).
- In 2001, instead of uniformly spreading stockpiled soil over revegetation areas, CMM distributed stockpiled soils randomly over reclamation areas as distinct mounds and small hillocks. The result was an increased variety of topography and substrate that was thought to encourage plant community diversity. In addition, the darker color of the stockpiled soil contrasted with the lighter color of mine waste surfaces, ameliorating the visual impact of CMM disturbance from a distance (11th Report, 2002).

7.0 SEED COLLECTION

A seed collection program was initiated at CMM in 1991 with the intent of using the collected seed for revegetation projects. Local seed is considered superior to that purchased from a commercial vendor due to its adaptations to the local climate, soils, and other site conditions. See Appendix B for the species collected each year.

Nine[6] species were collected in 1991 within 25 miles of CMM. Most of the seed was collected manually, and all was cleaned and certified at a laboratory before being returned to CMM for planting (1st Report, 1992). All seed for the 1992 collection was collected on the CMM site (2nd Report, 1993). All species collected in 1993 were within 20 miles of CMM (3rd Report, 1994). The 1994 seed collection, whose radius was not reported, resulted in a disappointing yield due to the low growing season rainfall (4th Report, 1995). All seed collected in 1995 was within 20 miles of CMM, including the mine property itself (5th Report, 1996).

Drought in 1996 and 1997 resulted in low seed volume at CMM (Appendix B; 6th and 7th Reports, 1997 and 1998). Because of the substantial variation in interannual precipitation at CMM, raised planter beds were constructed in 1997 specifically for the propagation of native grass seed, a highly desirable growth form for mine revegetation. With their fibrous root systems, grasses are particularly effective at controlling erosion which is an ongoing concern for mine revegetation such as on the long slopes of overburden. Each bed was plumbed for sprinkler irrigation and filled with sieved growth media. At the time of the 7th Report (1998), one bed had been planted with squirreltail seed both from greenhouse individuals as well as that collected locally.

The bulk of 2001 seed collection was performed during the week of June 25th with the assistance of temporary workers. Approximately 1,100 lbs of bulk seed was collected during this time, while approximately 50 lbs additional seed was collected on July 27th. Bulk seed was collected by direct harvest from plants, from underneath shrubs, and from that windblown into depressions and washes. Care was taken to not collect weed seeds along roads or disturbed areas. Bulk seed was screened to remove large branches, stones, and debris, and then blended together to create a more homogeneous mixture (11th Report, 2002).

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[6] This number was stated to be ten, but only nine were specified.

Bulk seed collection as the sole seed source has demonstrated to be successful at other desert mines. The advantages of collecting bulk seed from plants and the ground are that (11^{th} Report, 2002):

- Seeds may be naturally inoculated with VAM from spores and soil particles
- A large variety of seeds, including annuals, will be collected, thereby increasing plant community diversity
- Large quantities can be collected locally within a short time with the assistance of additional personnel
- Seed shed at different times of the year and over the course of several years will be included
- Seeds can be sown immediately without a long storage period or concern for germination requirements

8.0 RECLAMATION, REVEGETATION, AND VEGETATION ANALYSIS

Reclamation occurred in two principal phases. The first phase addressed the reclamation of all areas of CMM that ceased operations before mining was complete; these areas included pits, dumps and roads. The inception of reclamation and revegetation activities was in 1990 and 1991 (1st Report, 1992). As of December 1999, 78.2 acres had been reclaimed at CMM, and a year later this figure was 128.7 acres (10th Report, 2001).

The second reclamation phase, which started in mid-2001 immediately following the discontinuation of active mining at CMM, was in response to the closure of mining activities and addressed the rinsing, decommissioning, and final reclamation of the leach heap. A total of 330 acres were reclaimed in 2001, bring the total reclaimed acreage at CMM at that point to 470 acres. In 2001 approximately 315 acres were still in use by CMM and remained to be reclaimed including the leach heap pad, processing facilities, a few remaining roads, and the administration office (11th Report, 2002).

This section is arranged chronologically. Table 7 summarizes all reclamation activities and associated research at CMM throughout the duration of mining and closure activities. In several cases, the same project was reported on in more than one Annual Revegetation Report; these are summarized together and the Annual Revegetation Reports are cited accordingly.

All available information on reclamation, revegetation, and research projects is reported herein. If a project description appears incomplete it is because the original authors of the project or of the Annual Revegetation Report did not report the project in its entirety, or abandoned a project before it was complete.

8.1 PLANT HORMONE EXPERIMENTS

"Superthrive" plant hormone (25 drops per ½ gal [presumably water] per plant) and a root growth stimulant (primarily vitamin B_1) were applied to transplants, presumably in the north nursery, on May 28th, June 7th, and August 15th, 1991. A single row in the north nursery served as a control. In addition, four Joshua tree individuals in the North nursery received "Green Cloud" anti-transpiration treatment in May of 1991 (1st Report, 1992).

Table 7. Chronological summary of reclamation activities and formal research, CMM, 1990-2001.

See Appendix D for all related publications.

Year(s)	Activity	Section Ref.
1990-1, 1994, 1998	Baseline vegetation analysis	9.1
1990-7	Road reclamation	8.2
1991-2	Superthrive hormone and Green Cloud anti-transpiration comparisons	8.1
1991-4	Erosion control	8.3
1992	Seeding of soil stockpiles	6.0
1992-4	Soil stockpile quality	9.2
1992-5	Revegetation around administration parking lot	8.4
1993	Expansion of West overburden pile	8.6
	Packrat midden studies	8.7
	Establishment of experimental plots on South Overburden	8.8
	Heap leach material as a growth medium	9.3
1993-4	Mulch comparisons, South Overburden	8.8.1
	Soil properties of different plant communities	9.5
	Revegetation of overburden piles	9.6
	Determination of mulch effects on overburden microbial populations	9.7
	Determination of CMM dustfall quality and quantity	9.8
1993-6	VAM studies	8.5, 9.20
1994	Stockpiled soil turned into South Clay Pit Reclamation Area	6.0
	Growth medium comparisons	8.10
	Use of deflector shields to aid revegetation of overburden piles	9.9
	Tests of heap leach material in supporting plant growth	9.12
	Protection for plant establishment	9.13
	Container types and soil mixes for desert restoration	9.14
	Evaluation of containerless transport on burrobush shrubs	9.15
1994-5	Herbivore exclosure experiments	9.16
1994-9	Greenhouse experiments	4.2
1994, 1998-2000	Rock staining	8.9
1994, 2001	Inventory, collection, blending, and sowing of native plant seed	8.14, 9.11
1995	Spacing patterns in Mojave desert woody species	9.17
1995-6	Northwest Rim drill pads and road revegetation	8.2.4
1996-2000	South Overburden revegetation	8.8.2, 8.8.3, 8.8.4
1996, 2001	Inventory and transplanting of salvaged and propagated plants. In 1996: >2000 transplants to Drill Road north of Hart (Rd #4), South Overburden Hill #1 (“Revegetation Area 1”), Green and Gold Area (Drill Rds #1, 3, 7, 8, 9, 11), Heap Leach Test Plot, Northwest Rim Drill Rds, and Well #39 Rd	8.2.1, 8.2.4, 8.2.6, 8.8.2, 8.11, 8.13
1997	Green & Gold Rd #7 restoration project	8.2.5
1997	Reclamation and revegetation of exploration drill roads	8.2.6
1997-2000	Fencing	8.8.5
1998	Characterization of soils and water in local blackbush communities	9.18
	Evaluation of DNA from two distinct *Salsola* strains	9.19
2001	Grading, sloping, and ground surface preparation of 345 acres	8.12

Superthrive was initially observed to rejuvenate previously declining plants (1st Report, 1992). However, by the second growing season (1992), Joshua trees that were not treated with Superthrive performed at least as well as those that were (2nd Report, 1993). Green Cloud applications appeared to have no effect (1st Report, 1992).

8.2 ROAD RECLAMATION

In 1990-1991, reclamation activities were limited to four exploration roads in December 1991, as mining operations on the site were also in their beginning stages. The roads totaled 2,469 linear feet and 1.36 acres (2nd Report, 1993). A D9 Dozer with two 48" rippers followed by a 235-Excavator (backhoe) with two 8" rippers were used to break up the compacted soil. The resulting topography was irregular, approximating ideal conditions for seed and water retention. Native plants were immediately transplanted to the prepared areas. Which roads, transplanting procedures used, or species selected were not explicated (1st Report, 1992).

Table 8 summarizes revegetation work on Revegetation Roads at CMM from 1992 to 1996, and subsections 8.2.1 - 8.2.6 provide additional detail.

8.2.1 Revegetation Road #4 (Mine Access & Exploration Road North of Hart)

In February of 1992, thirty-six linear miles comprising thirty-nine acres of berms lining the mine access and exploration road north of Hart (Revegetation Road #4; 5th Report, 1996) were broadcast-seeded and harrowed with a chain link harrow.[7] The seed used was locally collected seed in combination with the mix below as provided by Granite Seed Company (Lehi, Utah).

Species	State of Origin
Filaree (*Erodium* sp.)	CA
Creosote bush	NV
Winterfat	NV
Palmer penstemon	UT
Sideoats grama	TX
Blue grama	TX
Galleta grass	TX
Desert almond	NV
Flax	UT
Fourwing saltbush	NV
Three-awn	AZ

See Appendices A and B for scientific names if not specified.

[7] Records of early revegetation efforts on Revegetation Road #4 are inaccessible (4th Report, 1995), or "inadequate" (5th Report, 1996). There is little agreement among Annual Revegetation Reports regarding the precise nature of this early work on Road #4.

As of January 1993, the seeding work had shown “little success” (2nd Report, 1993). However, plentiful precipitation in early 1993 supported the emergence of fourwing saltbush, Palmer penstemon, apricot mallow, and flax. By mid-summer, fourwing saltbush and apricot mallow had been heavily grazed and were no longer represented on the portion of the road crossing the Lanfair Valley grazing allotment. On the other hand, fourwing saltbush was as tall as four feet in the Crescent Peak grazing allotment, which had not been grazed since 1991 (3rd Report, 1994).

Table 8. Revegetation work on Revegetation Roads, CMM.
Data are from 4th, 5th, and 6th Reports (1995, 1996, and 1997). See Appendix A for scientific names. Note that only work on numbered roads is summarized here; see subsections below for information on Walking Box Ranch (subsection 8.2.2), Big Chief Hill (subsection 8.2.3), Razorback Butte, the Northwest Pediment, and Egg Dome (subsection 8.2.6).

Revegetation Road #	Date planted	Species (Number planted)	Condition (Survey date)
4 (for mine access & exploration N of Hart)	Feb 1992	Seed mix (Table 2B)	“Unsuccessful” (Dec 1992)
	1994	4 Creosote bush	4 dead (Dec 1995)
	Unknown	Joshua tree	7 excellent (1996), 12 dead (Dec 28, 1994)
		3 Mojave yucca	3 excellent (1996)
		8 Creosote bush	3 good, 5 dead (Dec 28, 1994)
		Banana yucca	1 excellent (1995)
	1995	7 Joshua tree	2 poor, 5 dead (1996)
		3 Mojave yucca	3 dead (1996)
		6 Banana yucca	6 dead (1996)
		5 Barrel cactus	4 excellent, 1 dead (1996)
	1996	5 Joshua tree	5 excellent (1996)
		2 Mojave yucca	2 excellent (1996)
7	Mar & Jul 1995	7 Joshua tree	4 excellent, 3 poor (1995)
		4 Barrel cactus	3 excellent, 1 dead (1995)
8	Mar & Jul 1995	4 Joshua tree	2 excellent, 2 poor (1995)
		3 Barrel cactus	2 excellent, 1 dead (1995)
9	Mar & Jul 1995	21 Joshua tree	9 excellent, 11 poor, 1 dead (1995)
		3 Barrel cactus	3 excellent (1995)
		2 Mojave yucca	1 excellent, 1 poor (1995)
10	Mar & Jul 1995	4 Joshua tree	1 excellent, 3 poor (1995)
11	Mar & Jul 1995	10 Barrel cactus + 38 unspecified cacti	
12 (NW Rim)	March 1995	Joshua tree and banana yucca (see Section 8.2.4)	See Section 8.2.4
13 (NW Rim)	March 1995		

On December 28, 1994, straw was placed along eroded areas on the road and four creosote bush and one banana yucca propagated from seed in the greenhouse were planted at the same time near the eroded areas (4th and 5th Reports, 1995 and 1996). On the same day a survey was performed of the plants resulting from the work in February 1992: of the tagged plants (records of the work performed were missing), 7 Joshua trees on the road were rated in good health and 12 were dead. All 3 Mojave yucca were in good health, 3 creosote bush were in good health and 5 were dead, and 1 banana yucca was in good health (4th Report, 1995). In 1995, 19 of the original salvaged and replanted plants could be identified by their metal tags, 11 of which (7 Joshua trees, 3 Mojave yucca, and 1 banana yucca) were alive and in excellent health and 8 of which were dead (5th Report, 1996).

In 1996, Revegetation Road #4 received an unspecified number of over 2,000 transplanted native plants representing 28 species (6th Report, 1997). See Table 8 for other areas that received transplants from the same group. The native species planted were (see Appendices A and B for Latin nomenclature):

- Apricot mallow
- Banana yucca
- Barrel cactus
- Beavertail cactus
- Blackbush
- Box thorn (*Lycium andersonii*)
- Burrobush
- Catclaw
- Club/mat cholla
- Clustered barrel cactus
- Creosote bush
- Desert needlegrass
- Desert willow
- Four-wing saltbush
- Galleta grass
- Golden cholla
- Green encelia
- Hedgehog cactus
- Indian ricegrass
- Joshua tree
- Mojave prickly-pear
- Mojave yucca
- Muhly
- Pancake prickly-pear
- Paper daisy
- Three-awn
- Shrubby encelia
- Squirreltail

8.2.2 **Walking Box Ranch HQ and Road**

In 1992, several hundred plants were transplanted to Walking Box Ranch. An unspecified number were planted in porous gravel "very different" from the soils at the nursery and received some irrigation. At the end of 1992, 125 barrel cacti had been surveyed; of these, 77% were in excellent condition, 2% were in poor condition, and 22% had died (2nd Report, 1993).

In April of 1993 the road in front of Walking Box Ranch headquarters was re-routed and a portion of the original thoroughfare treated for revegetation. The road was ripped once in April and 5 salvaged Joshua trees were planted at the southern end of the road. The road was ripped again in May however seeding and transplanting were postponed for the season since winter precipitation had ceased. In December the 5 Joshua trees were in excellent condition (3rd Report, 1994).

In January 1994, Owen Reclamation transferred 4 boxed Joshua trees from the CMM Administration parking area to the Walking Box Ranch road and planted the trees with a track hoe. Seed was manually distributed at 40 lbs/acre in very windy conditions. No seed germinated in 1994, presumably due to dry climatic conditions. In March of 1994, 7 Joshua trees from the salvage area near Walking Box Ranch were planted manually, and in December, 10 Indian ricegrass, 7 creosote bush, 2 golden cholla, and 2 catclaw individuals were planted (4th and 5th Reports, 1995 and 1996). On October 16, 1995, 3 Indian ricegrass, 3 creosote bush, and 2 golden chollas were in excellent health; 1 catclaw was in poor health; and 7 Indian ricegrass, 4 creosote bush, and 1 catclaw were dead (5th Report, 1996).

On October 16, 1995, 2 catclaws, 1 creosote bush, and 2 apricot mallow propagated from seed in the greenhouse were planted on the road revegetation area in front of the ranch (5th Report, 1996). December 1996 surveys of plant health in this area indicated that 37% were in excellent condition, 7% were in poor condition, and 56% were dead. These surveys were considered preliminary, as Indian ricegrass is dormant at this time and could have been interpreted as dead. Catclaw and apricot mallow had also experienced disproportionate damage by rodents (6th Report, 1997).

8.2.3 **Big Chief Hill**

In January 1994, Owen Reclamation "pulled back" a road measuring approximately 450 feet on the south side of Big Chief Hill with a track hoe and followed with manual seeding. The seed mix was unspecified (4th Report, 1995).

8.2.4 **Northwest Rim Drill Pads and Road Revegetation**

The northwest rim contained three drill pads (#1, #2, and #3) and two short drill roads (Revegetation Roads #12 and #13). Revegetation work began in this area in March of 1995. Drill pads #1-3 were manually seeded on non-windy days and all areas planted with 19 Joshua trees and 1 banana yucca salvaged in 1995 from the leach pad expansion (see Section 5.0). By December, 14 of the 20 plants were rated as being in excellent condition and the remainder, including the banana yucca, were in poor condition. Also by this time *Ephedra* sp., apricot mallow, Indian ricegrass, and galleta grass had seeded in naturally (5th Report, 1996). By the time of the 6th Report (1997) over 75% of plants on the northwest rim were rated as being in excellent condition.

In 1996, the Northwest Rim drill roads received an unspecified number of over 2,000 transplanted native plants representing 28 species (6th Report, 1997). See Section 8.2.1 for a list of the species used and Table 8 for other areas that received transplants from the same group.

8.2.5 **"Green and Gold" Revegetation Roads**

Revegetation Roads #7-10 were ripped and recontoured in February 1995 and recontouring was repeated in September of the same year. A total of 48 cacti, all salvaged in 1995 from expansion of the south overburden (Section 5.0) and the leach pad, were planted along the four roads in March and July (see Table 8; 5th Report, 1996).

In 1996, Drill Roads #1, 3, 7, 8, 9, 11 (the "Green and Gold Area") received an unspecified number of over 2,000 transplanted native plants representing 28 species. Drill Road #4 received transplants from the same set of individuals (6th Report, 1997). See Section 8.2.1 for a list of the species used and Table 8 for other areas that received transplants from the same group.

In 1997, Green & Gold Road 7 was the site of a restoration project by a California State University class taught by Dr. Ray Franson. The exercises included outplantings of 5 creosote bush, 2 apricot mallow, 2 barrel cactus, 2 blackbush, 2 Mormon tea, 1 Joshua tree, and 1 beavertail cactus (7th Report, 1998).

8.2.6 **1997 Reclamation and Revegetation**

During 1997, CMM reclaimed and seeded or planted 5.6 miles of exploration drill roads totaling 8.1 acres in three areas (7th Report, 1998). The roads were:

- Razorback Butte: Nevada Roads (65 and 66) and California Roads (P1, P2, and P3).

  The seed mix used on these roads included apricot mallow, California buckwheat, cheesebush, cotton thorn, creosote bush, fourwing saltbush, goldenhead, green encelia, Mojave yucca, and Mormon tea. Outplantings included 83 Mojave yucca, 71 barrel cactus, 44 catclaw, 42 golden cholla, 38 Mormon tea, 36 barrel cactus, 24 hedgehog cactus, 17 Mojave aster, 15 creosote bush, 13 clustered barrel cactus, 13 odora (*Porophyllum gracile*), 7 burrobush, 7 green encelia, and 3 Parish's viguiera (7th Report, 1998).

- Northwest Pediment: Roads B, C, and D.

  The seed mix used on the Northwest Pediment roads included apricot mallow, boxthorn, California buckwheat, catclaw, creosote bush, desert marigold, fourwing saltbush, galleta grass, green encelia, Indian ricegrass, Joshua tree, Mojave aster, Palmer penstemon, paper daisy, purple three-awn, sideoats grama, and winterfat. Outplantings included 24 barrel cactus and 12 each of golden cholla, hedgehog cactus, and Mojave yucca (7th Report, 1998).

- Egg Dome: Roads 22, 25-30, 31A, 32, 33, and 35.

  Due to treacherous terrain and loose substrate on Egg Dome, outplantings and traditional seeding methods, which require manual raking, were not practical. In addition, the high winds at Egg Dome were anticipated to remove seeds that were traditionally broadcast. Seeds were instead cemented into pellets with inorganic nutrients by Nature Nu Corporation. The seed mix used included apricot mallow, brittlebush, California buckwheat, cheesebush, creosote bush, fourwing saltbush, goldenbush, green encelia, Mormon tea, muhly, sticky snakeweed, and viguiera (7th Report, 1998).

8.3 EROSION CONTROL

Two major erosion control experiments were executed at CMM between 1991 and 1994. Erosion control tests intended for 1992 were abandoned due to the realization that the plots were not ideally located (2nd Report, 1993). The intended location was close to the road leading to the wellfield. Also, in February 1995, straw and rocks were used to fill an erosion channel formed by runoff from the administration parking lot, but were ineffective in preventing further erosion due to a significant storm in September (see also Section 8.4; 5th Report, 1996).

8.3.1 **October 1991 Comparisons of Erosion Control Techniques**

In October of 1991 several plots with a slope of approximately 3:1 were established on the south-facing slope of the north nursery to test six erosion control techniques:

- Crimping grasses and seed
- Crimping grasses only
- Crescent catchments with tortoise fence reinforcement
- Crescent catchments with rock
- Excelsior
- Straw bundles in dams

All but the crimping treatments exhibited some potential for erosion control (1st Report, 1992).

8.3.2 **POZOCAP experiments**

In 1993,[8] Owen Reclamation delineated four acres on the lowest terrace on the west overburden stockpile[9] into sixteen ¼-acre (100 × 100-ft^2) plots (3rd Report, 1994). The experiment called for four replicates of the following treatments:

1) Growth media + POZOCAP (Chemstar Lime), an erosion control/revegetation treatment intended for steep slopes such as the faces of overburden piles
2) Growth media alone (no POZOCAP)
3) POZOCAP alone (no growth media)
4) Control (no growth media or POZOCAP)

All treatments were randomly distributed. Soil from stockpile 1A (Table 6) was applied at a rate of 15 yd^3/acre by a track hoe at the top of the overburden slope. In the POZOCAP treatments, an unspecified seed mix was sprayed concurrently with POZOCAP. In the treatments without

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[8] An area for the demonstration of POZOCAP (Chemstar Lime) was intended for establishment for February 1993 on the west face of the west overburden stockpile (2nd Report, 1993). Application failures in November of 1992, however, prompted Chemstar Lime to reformulate the treatment to allow mixing with seed before distribution.

[9] The 4th Report (1995) describes this test area as the "south clay pit reclamation area."

POZOCAP, the seed mix was dispersed manually. The days on which treatments were applied were very windy. As of January 1995, due to the low rainfall in 1994, no seeds had germinated in the plots (4th Report, 1995).

8.4 Revegetation around the Administration Parking Lot

In February of 1992 the areas immediately to the south and west of the administration parking lot were revegetated with thirty-four individuals representing eleven species.[10] In October and November of the same year 53% of the plants were in excellent condition, 41% were in poor condition and 6% were dead. Also in November 1992 cattle decimated populations of apricot mallow in the area (2nd Report, 1993). In the spring of 1993 numerous fourwing saltbush individuals sprouted in this area; it was uncertain whether this population was volunteer or from sown seed. Many of these fourwing saltbush individuals attained heights of four feet before cattle grazed them to less than two feet tall, which they remained for the rest of 1993 (3rd Report, 1994). The seed of apricot mallow, Palmer penstemon, Indian ricegrass, desert marigold, bee plants (*Cleome* sp.), and the exotic foxtail chess was observed to germinate on bare ground with no supplemental growth media (3rd Report, 1994).

Although quantitative data were lacking, the 3rd Report (1994) noted that Joshua trees planted with a tree spade in this area were doing well, in contrast to those planted by hand without added growth media. The 4th Report (1995) called attention to the fact that the boxed Joshua trees previously reported as being planted with a tree spade "in fact were laboriously hand-dug and boxed in place." As of 1994, 87% of these boxed Joshua trees, summarized with those at the north nursery, were in excellent condition, 4% in poor condition, and 11% dead. Eleven of fifteen hand-planted Joshua trees without supplemental stockpiled soil had died by June of 1994. The remaining four hand-planted Joshua trees and one hand-planted Mojave yucca each received four gallons of soil from stockpile 3A (see Table 6). All *Yucca* species planted with a tree spade, which includes the root mass and surrounding soil, were doing well as of 1994 (4th Report, 1995).

In February 1995, three Joshua trees, one Mojave yucca, and three blackbush salvaged from the area being cleared for the Oro Belle haul road were planted in front of the administration

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[10] Also in February 1992, seventeen Joshua trees and eight Mojave yucca were tree-spaded along the tortoise fence west of the administration building.

building. In December all of the *Yucca* species were "doing well" and one of the blackbush was still alive. Also in February 1995, straw and rocks were used to fill an erosion channel formed by runoff from the parking lot, but were ineffective in preventing further erosion due to "the big storm" in September (5th Report, 1996).

8.5 VESTICULAR-ARBUSCULAR MYCORRHIZAE (VAM) STUDIES

On August 26, 1993, soil from several locations at CMM (and Joshua Tree National Park) was sent to Dr. Joe Morton at the International Vesicular-Arbuscular Mycorrhizae (VAM) Fungus Collection (INVAM) and West Virginia University for isolation, culture, identification, and purification of VAM spores (3rd and 5th Reports, 1994 and 1996). VAM inoculation in plant roots is important for nutrient acquisition, and most vascular plants rely on these symbiotic associations. The CMM soils yielded three VAM cultures (5th Report, 1996).

In June 1995 the revegetation ecologist began propagation of the VAM cultures in calcined clay using sorghum (*Sorghum bicolor*) as the host plant to build up a large VAM volume. In July the growth medium was changed to fine- to large-grained sand. The cultures were harvested in November 1995, and were sampled and stained in December to verify colonization of plant roots (5th Report, 1996). Percent colonization of the 6 CMM VAM samples was very low at 3, 3, 5, 12, 32, and 44 percent (6th Report, 1997).

See Section 9.20 for descriptions of research applying these locally collected VAM strains.

8.6 WEST OVERBURDEN PILE

On July 28, 1993, workers initiated the upward expansion of the west overburden pile to cover the clay pit scar on the west side of Big Chief Hill. As of January of 1994, the west overburden pile had three terraces, the top one of which was complete. A total of 4200 cubic yards of soil was transferred from stockpile 1A (Table 6) to each of the three terraces of the west overburden pile to initiate the revegetation process (3rd Report, 1994).

8.7 PACKRAT MIDDEN STUDIES

In 1993, packrat middens dating to the mid- to late 19th century were sampled in order to gain an understanding of the plant community composition of CMM prior to cattle grazing, which initiated in the 1880s, and mining activities, which started in 1907. Of particular concern was whether the woody species Utah juniper and catclaw were present in the area currently occupied by CMM (3rd Report, 1994).

On January 22, February 16, and March 24 of 1993, representatives from Dames and Moore (Las Vegas, NV) obtained a total of seven packrat (or woodrat) middens, often solidified massed of plant debris accumulated by *Neotoma* individuals. The collected middens ranged in age from 121 to 2290 years B.P. (determined by radiocarbon dating) and in elevation from 1320 to 1355 m.[11] The contents of each midden were sorted, identified, and quantified (3rd Report, 1994).

A total of seventeen plant species were identified; species diversity showed no consistent chronological trend. Utah juniper was not found in any of the sampled middens and catclaw was found in one midden. The three youngest middens sampled (approximately 120 years B.P.) all contained storksbill, a Eurasian weed introduced in the 19th century (3rd Report, 1994). The full report is described in McVickar, J.L. (Dames & Moore, Las Vegas), *Documentation of pre-disturbance vegetation of the Castle Mountain Mine area through the analysis of packrat middens*. A graphic representation of relative abundance of each species was provided in the 4th Report (1994).

8.8 SOUTH OVERBURDEN EXPERIMENTAL PLOTS

In October of 1992, the site for overburden experimental plots was delineated (location unspecified). The intended experiments were to compare the effects of growth media, broadcast seeding, and pitting on seedling establishment (2nd Report, 1993). The originally designated locations for these revegetation experiments were relocated to the South Overburden, a portion of which was ready for experimental use on April 21, 1993. Approximately 500 square feet on the South Overburden was ripped in July for two of the experiments (3rd Report, 1994). All South Overburden experiments are described in the subsections below. The 9th Report (2000), Figure 9, illustrates the various Revegetation Areas on the South Overburden.

8.8.1 Mulch Comparisons

Forty-five individuals each of creosote bush and Indian ricegrass seedlings were planted in July 1993 on the South Overburden as part of the SDSU Revegetation Research Grant. The seed-

[11] Packrat midden density at CMM is "very high;" however, only those protected from weathering (such as that incurred from precipitation) were preserved well enough to offer conclusive data.

lings were grown at the California Department of Forestry, L.A. Moran Reforestation Center (Davis, CA) from seed collected in July at CMM. In the interest of observing their differing effects on plant growth and populations of soil microflora, three mulch treatments – straw, rice hulls, and wood chips – were applied (3rd Report, 1994). Cattle, only somewhat deterred by barbed wire, grazed the plots in May 1994. Observations in 1994 indicate that the mulched plots, particularly the straw, had higher populations of fungi and bacteria than non-mulched plots. Because such microorganisms generally contribute to soil quality, these initial results suggest that mulching may benefit revegetation on overburden substrates (4th Report, 1995).

In December of 1994 a 50 × 170-foot area north of the catclaw plot on the south overburden pile (see Section 9.3) was ripped in preparation for a mulching experiment to be initiated in 1995 (4th Report, 1995). No further details were reported.

8.8.2 **Revegetation of Areas #1 and #3**

In 1996, Revegetation Area (or Hill) #1 received an unspecified number of over 2000 transplanted native plants representing twenty-eight species (6th Report, 1997). See Section 8.2.1 for a list of the species used and Table 8 for other areas that received transplants from the same group. The 9th Report (2000) stated that Area #1 on the South Overburden was seeded in 1996 in addition to receiving transplants.

In 1997, 7.4[12] acres in Areas #1 and #3 of the South overburden were seeded and planted (7th Report, 1998), as described below.

- Area 1A: The seed mix used included apricot mallow, boxthorn, California buckwheat, catclaw, creosote bush, desert marigold, fourwing saltbush, galleta grass, green encelia, Indian ricegrass, Joshua tree, Mojave aster, Palmer penstemon, paper daisy, sideoats grama, three-awn, and winterfat. The supplemental seed mix included black-stem, burrobush, California buckwheat, cheesebush, cotton thorn, creosote bush, desert marigold, fourwing saltbush, goldenhead, green encelia, Mojave aster, Mormon tea, muhly, paper daisy, and three-awn. Outplantings included 110 creosote bush; 64 Mormon tea; 63 golden cholla; 48 each of cotton thorn, fourwing saltbush, and Mojave aster; 45 cheesebush; 42 Mojave prickly-pear; and 32 catclaw (7th Report, 1998).

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[12] The 7th Report (1998) also states this number to be 7.8 acres.

- Area 1B: Supplemental outplantings, which are used to augment regular plantings usually in response to water stress, included 24 creosote bush, 12 galleta grass, 9 each of fourwing saltbush and Mojave prickly-pear, 8 cotton thorn, 5 hedgehog cactus, 5 beavertail cactus, and 2 golden cholla (7th Report, 1998).

- Area 3: The seed mix used included black-stem, burrobush, California buckwheat, cheese-bush, cotton thorn, creosote bush, desert marigold, fourwing saltbush, goldenhead, Joshua tree, Mojave aster, Mormon tea, paper daisy, and three-awn. Outplantings included 62 Moja-ve aster; 47 cheesebush; 45 fourwing saltbush; 31 each of bladder sage, boxthorn, and Mor-mon tea; 30 cotton thorn; 30 Joshua trees; 27 creosote bush; 22 blackbush; 14 burrobush; 7 Mojave yucca; and 6 golden cholla (7th Report, 1998). In the spring and summer of 1998 this area was planted with 103 greenhouse-raised cacti. The species transplanted were beavertail cactus, golden cholla, hedgehog cactus, Mojave prickly-pear, and pancake prickly-pear (8th Report, 1999).

8.8.3 **Revegetation Areas #4-9**

Forty-six acres on the South Overburden were introduced to the revegetation program in 1998. During this year, Revegetation Areas #4 through 9 were ripped, covered with growth media, mechanically seeded at 22.5 pounds/acre, harrowed, and planted with native species (8th Re-port, 1999).

- In 1998, Areas #4 and #5 were designed to compare reclamation success on the south face of the South Overburden with and without growth media topdressing, which Area #4 received and Area #5 did not. The seed mix used for these areas included burrobush, California buck-wheat, creosote bush, desert marigold, fourwing saltbush, goldenhead, green encelia, Joshua tree, Mojave aster, Mojave yucca, *Ephedra nevadensis*, muhly, paper daisy, three-awn, and winterfat. In addition, Area #4 received 64 *Ephedra nevadensis*, 47 cheesebush, 39 bladder sage, and 33 fourwing saltbush, all nursery-grown transplants (8th Report, 1999).

- In 1998, Area #6 received a seed mix including blackbush, burrobush, cotton thorn, creosote bush, desert marigold, fourwing saltbush, green encelia, Indian ricegrass, Joshua tree, *Pleu-raphis* sp., three-awn, and winterfat. Areas #5 and #6 received 186 blackbush, 64 *Ephedra nevadensis*, 46 boxthorn, 40 bladder sage, 40 Mojave prickly pear, 32 cheesebush, 22 golden cholla, 10 beavertail cactus, and 10 hedgehog cactus nursery-grown transplants (8th Report, 1999).

- In 1998, Area #7 was contoured into 3 hills including a depression and a flat area, covered with growth media from the Milma Patent area, and planted with 155 blackbush and 46 box-thorn at high densities as well as salvaged hedgehog cactus and clustered barrel cactus (8th Report, 1999).

- In 1998, twenty-five acres of the 46-acre Area #8 was contoured in addition to being ripped and covered with growth media. All 335 plants targeted for salvage from the leach pad expansion area, in addition to twenty-one shrubs, were transplanted to this 25-acre area. Instead of the bare-root method, all transplants were tree-spaded and their rootballs wrapped in burlap and set in wire cages. The seed mix (apricot mallow, banana yucca, beardtongue, blackbush, black-stem, brickellbush, burrobush, California buckwheat, creosote bush, desert marigold, *Ericameria* sp., fourwing saltbush, galleta grass, goldenhead, green encelia, hop-sage, Indian ricegrass, interior goldenbush, Joshua tree, Mojave aster, Mojave yucca, Mormon tea, muhly, Palmer penstemon, paper daisy, rubber rabbitbrush, and viguiera) used for this area included that collected onsite as well as that purchased from the Granite Seed Company (California buckwheat, galleta grass, and Indian ricegrass) to meet seeding requirements (8th Report, 1999).

  In 1999, Sections 1 and 2 of Area #8A received 947 nursery-grown plants representing twenty species in addition to transplants from salvage operations (see Section 5.1).

- In 1998, Area #9 was contoured, ripped, and covered with growth media (8th and 9th Reports, 1999 and 2000). In 1999, Area #9 received forty-three transplants from salvage operations (see Section 5.1).

Also in 1999, two drill roads adjacent to Area #8A received reclamation treatments. The roads were planted with 111 greenhouse-grown creosote bush, *Ephedra nevadensis*, and three-awn, and thirty salvaged barrel cacti. Recontouring the south face of the South Overburden was completed in preparation for hydroseeding, and similar work was initiated on the southwest corner and the west face of the South Overburden (9th Report, 2000).

8.8.4 **2000 Activities**

A total of 50.5 acres on the South Overburden were reclaimed in 2000 (10th Report, 2001).

- The 22.9-acre South Face slope was seeded at 22 lbs/acre. The seed mix included banana yucca, barrel cactus, blackbush, black-stem, blue grama, box thorn, brickellbush, brittlebush, burrobush, California buckwheat, cheesebush, cotton thorn, coyote melon, creosote bush, desert marigold, desert needlegrass, *Ephedra nevadensis*, flax, fourwing saltbush, galleta grass, goldenhead, Indian ricegrass, Joshua tree, Mojave aster, Mojave prickly-pear, Mojave yucca muhly, paper daisy, *Phacelia campanularia*, sand dropseed, sideoats grama, squirreltail, sticky snakeweed, three-awn, turpentine brush, *Vulpia octoflora*, winterfat, and woolly bur-sage (10th Report, 2001).
- The 14.9-acre East Face slope was recontoured and seeded (10th Report, 2001).
- A new 12.7-acre area was ripped and seeded on the northeast top of the overburden area (10th Report, 2001).
- Fencing was added (see Section 8.8.5).

8.8.5 **Fencing**

Fifty-five acres on the South Overburden were enclosed in 1997 with a four-strand barbed wire fence intended to keep out roaming cattle (9th Report, 2000). This fence was expanded in 1998 and again in 1999. The 1999 fencing improvement tied into an existing chain link fence enclosing the leach pad and administration areas, and a high wall overlooking the Lesley Ann Pit. As such, cattle were theoretically excluded from virtually the entire mine site, although a breach allowed cattle to access Area #3 on the South Overburden, seriously trampling it. Cattle later entered the site from the north, off of Egg Dome, depressing 1999 monitoring results (9th Report, 2000). Additional fencing was installed in 2000 around the east end and top of the South Overburden to exclude cattle grazing. At this point range cattle were being removed from all grazing areas surrounding CMM (10th Report, 2001).

8.9 **ROCK STAINING**

In March of 1994, the exposed white rock above the top overburden bench on the South Clay Pit Reclamation Area was sprayed with Permeon. Permeon is intended to approximate the appearance of natural desert varnish as observed on surrounding, undisturbed rock (4th Report, 1995). No observations were recorded.

Attempts were made over the course of the 1998-2000 growing seasons to find a mixture to stain rock waste and cut rock slopes to simulate the color of the surrounding undisturbed desert substrate. Two solutions – ferrous sulfate and manganous sulfate – in sodium hydroxide carrier solutions were evaluated. Three seasons of monitoring indicated that such staining was unnecessary, as (1) the varnished rock surface weathered quickly and did not retain the stain and (2) much of the rock waste and cut slopes surrounding the varnish test areas had weathered to a shade similar to the test areas. Thus, natural processes reduced the color contrast between disturbed and undisturbed areas (11th Report, 2002).

8.10 GROWTH MEDIUM COMPARISONS

In June of 1994, fifty-eight Indian ricegrass individuals, started in containers with a peat-based potting soil mix, were planted in the north nursery. All died by September of the same year, their deaths speculated to be the result of over-watering. In August, more than 100 muhly individuals in two 6" containers with the same peat-based potting soil mix were planted adjacent to the ricegrass plot. The muhly was watered the day of planting as well as the day after. All muhly individuals died. These results indicated that the use of peat should be minimized in the greenhouse (4th Report, 1995).

In 1994, catclaw seedlings were grown in heap leach material in the greenhouse (month[s] unspecified). Plant growth was good if fine material such as overburden or stockpiled soil was added (4th Report, 1995).

8.11 HEAP LEACH REVEGETATION TESTS

One 100 × 100-foot plot on Cell 1 of the leach pad was established for *in situ* observations of plant establishment on heap leach material, which have greater value for field applications than controlled greenhouse experiments. Rinsing of the plot with water was completed in June 1995.[13] On June 27th; July 25th; August 25th; and September 13th, 14th, and 21st of 1995 the plants listed below were planted around the edges of the leach pad plot with soil from stockpile 4B.

One of the forty-two plants had died by the end of 1995 (5th Report, 1996).

[13] Leaching solution is NaOH (pH 12) with NaCN (5th Report, 1996).

4 Catclaw	3 Hedgehog cactus*	2 Muhly
4 Creosote bush	3 Mojave prickly-pear*	2 Golden cholla*
3 Burrobush	2 Apricot mallow	1 Beavertail cactus*
3 Fourwing saltbush	2 Indian ricegrass	1 Pancake prickly-pear*
3 Desert marigold	2 Blackbush	1 Joshua tree†
3 Galleta grass	2 Squirreltail	1 Banana yucca

Unless otherwise noted, all were grown from seed in the greenhouse except:
* = from cutting or transplant in greenhouse
† = transplanted from revegetation area
(see Appendix A for scientific names)

Nineteen plants representing four unspecified species were planted in the heap leach test plot in 1996. By the time of the 6th Report (1997), 95% of the plants in the test plot were rated as being in excellent condition, 2% as being in poor condition, and 3% as dead. Measurements of plant length, width, and height indicated that most of the plants in the test plot had grown substantially since initial planting despite the drought (see Figure 3, Section 2.4). In addition to those planted, two volunteer *Encelia* sp., one volunteer winterfat, and six volunteer creosote bush individuals established in the heap leach test plot in 1996 (6th Report, 1997).

In 1996, the heap leach test plot received an unspecified number of over 2000 transplanted native plants representing twenty-eight species (6th Report, 1997). See Section 8.2.1 for a list of the species used and Table 8 for other areas that received transplants from the same group.

8.12 GRADING AND GROUND PREPARATION

Reclamation and revegetation work in 2001 included grading, sloping, and ground surface preparation for subsequent revegetation. The objectives of grading were to (1) establish adequate soil drainage, (2) optimize the soil substrate, partly through the formation of water catchment basins, and (3) decrease the visual impact of disturbed areas by creating more natural topography. These procedures were performed on 345 acres at CMM in 2001 with the use of two dozers, a tracked backhoe, tree spade, motor grader, and a variety of smaller equipment (11th Report, 2002).

The overall grading procedure, in sequence, was as follows.

- Ripping and scarification of surfaces such as haul roads and equipment staging areas reduces compaction, creates an irregular surface that captures wind-dispersed seed, and increases the potential for seed germination via moisture enhancement. Studies of other reclaimed areas have indicated that ripping to depths of 2-3 feet by dozers, followed by rough-grading, reduced compaction and created a rough surface for seed catchment and soil conservation. Scarification, which is ripping to a shallower depth such as 15-18 inches, provides similar enhancements (11th Report, 2002).

- Rough-grading contours mine surfaces such as those found on overburden dumps and pit roads and bottoms into more natural, undulating landforms. Rough-grading in 2001 reduced side slopes to no less than 50% (11th Report, 2002).
- Application of stockpiled soil (referred to as "growth media" in Annual Revegetation Reports prior to 2000) was required by permit and reclamation stipulations (see Section 3.1) despite evidence that revegetation plots covered with growth media supported poor germination and growth of native perennials (see Revegetation Area #4 in Table 15). These weathered desert soils are often low in plant-available nutrients and organic matter and have poor water-holding capacity, observations that are not restricted to CMM (Bamberg, et al. 1994, e.g.; 11th Report, 2002).

  Instead of uniformly spreading stockpiled soil over revegetation areas, CMM distributed stockpiled soils randomly over reclamation areas as distinct mounds and small hillocks. The result was an increased variety of topography and substrate that was thought to encourage plant community diversity. In addition, the darker color of the stockpiled soil contrasted with the lighter color of mine waste surfaces, ameliorating the visual impact of CMM disturbance from a distance (11th Report, 2002).
- Fine-grading creates water microcatchment basins to facilitate seed germination, root development, and plant growth. In addition to retaining water, such catchments prevent sheet wash and erosion of side slopes. Microcatchments created in 2001 were located on the tops of overburden dumps, haul roads, pit bottoms, and other candidate areas in irregular patterns. The structures were less than 3 feet deep, 1-15 feet wide, and ranged from "a few" to approximately 50 feet in length. They were later seeded aerially (see Section 8.14; 11th Report, 2002).

8.13 TRANSPLANTS

Transplants were an integral component of the CMM revegetation program as a means to utilize the thousands of salvaged native plants (see Section 5.0 and Table 4), and also because a full-grown transplant, by virtue of its size and plant-soil interactions, offers more benefit to a newly revegetated ecosystem than a seed or a greenhouse-propagated seedling. The subsections below (8.13.1 - 8.13.3) summarize the transplant operations at CMM, all of which occurred in either 1996 or 2001.

8.13.1 **1996 Transplant Operations**

In 1996, over 2000 transplants representing twenty-eight native species were planted in eleven revegetation areas. These areas include the Drill Road north of Hart (Rd #4; see Section 8.2.1), South Overburden Hill #1 (or "Revegetation Area 1;" see Section 8.8.2), Green and Gold Area (Drill Roads #1, 3, 7, 8, 9, 11; see Section 8.2.5), Heap Leach Test Plot (see Section 8.11), Northwest Rim Drill Roads (see Section 8.2.4), and Well #39 Road (6th Report, 1997). See Section 8.2.1 for a list of the species planted in these eleven areas.

8.13.2 **2001 Transplant Operations**

In June 2001, all plants propagated in the greenhouse were moved outside under shade nettings to harden prior to the autumn 2001 transplanting operations. A total of 8203 plants were transplanted to CMM areas in 2001. The bulk of these were from the north nursery, while 750 barrel cacti were salvaged from the South Overburden. The species transplanted to the North Overburden dump and the South Overburden were: (11th Report, 2002):

2816 Mojave and banana yucca	397 hedgehog cactus
2515 barrel cacti	155 winterfat
758 Joshua trees	58 nipple cactus
589 "flat cactus species"	56 "miscellaneous" cactus
428 blackbush	36 beavertail cactus
406 "cane" cactus	

Transplants were arranged in clustered "garden areas." All plants were watered before and after transplanting. No fertilizer was used. Planting holes for salvaged and boxed plants were dug by backhoe, while those for potted plants and those in planters were dug by shovel (11th Report, 2002). Other methods were specific to the salvage and growth methods used with each plant, as follows:

- Salvaged plants were removed with the use of a tree spade and transported by trailer to the designated revegetation area. A backhoe was used to refill the holes around the larger *Yucca* species. The holes surrounding smaller succulents were refilled manually with a shovel. Replanting occurred within eight hours of initial displacement (11th Report, 2002).

- Boxed plants were transported in their boxes and placed in holes with a forklift, at which point the boxes were dismantled and the hole refilled with a backhoe (11th Report, 2002).
- Plants in planters were less than one foot tall. They were removed from the planters by loosening the soil with a shovel and removing as much soil as possible from the root system. Plants were transported by trailer and planted within eight hours of initial displacement (11th Report, 2002).
- Potted plants were transported in their pots and planted in the field with soil and roots undisturbed (11th Report, 2002).

8.13.3 **Watering Trailer**

To facilitate watering of transplants, in 1999 CMM constructed a water trailer by placing a 500-gallon Nalgene® water tank on a 2-axle chassis converted from a camp trailer. The chassis was covered with wood planking and a gasoline-powered water pump was installed with a 1” line to the tank. A hose reel was mounted next to the pump and 200 feet of hose added (9th Report, 2000).

8.14 SEEDING

Aside from the test plots and the 1992 seeding of soil stockpiles (see Section 6.0), seeding activities on CMM began during the week of November 26-30, 2001. Seed was sown soon after grading and ground preparation (see Section 8.12) while the soil surface was loose, uneven, and relatively soft in order to facilitate seed capture. Seeding was timed during these autumn dates to follow the onset of plant dormancy yet to precede winter precipitation; in addition, such timing eliminated the need to cover the seed, once dispersed, since imminent winter precipitation would incorporate the seed into the soil (11th Report, 2002).

At the initiation of the 2001 seeding activities there were approximately 9640 lbs of seed representing ninety-one plant species available in the straw bale house. Approximately 5070 lbs of seed were sown on 370 acres, leaving approximately 4570 lbs of seeds for subsequent use[14] (11th Report, 2002).

[14] The figure of 4570 lbs was calculated from the figures offered in the 11th Report (2002), i.e., 9640 – 5070 = 4570. The report, however, states that following 2001, there were approximately 3645 or 3500 (both numbers stated in different parts of the report) remaining for subsequent use.

Table 9 lists the plant species and weight of each in the four seed mixes used for 2001 seeding. The seed mix numbers used in Table 9 represent the following: 1 ≡ tops and sides of overburden dumps (North, South [top only], and Clay and Lesley Ann pits) and boneyard area; 2 ≡ Jumbo and OBHT (open) pits; 3 ≡ manual seeding of roads and smaller disturbances; and 4 ≡ South Overburden slopes. See also Table 10 for the target areas of each seed mix (11th Report, 2002).

Table 9. Seed mixes used for aerial and hand seeding, CMM, November 2001.
"C" next to the species name indicates that the species was considered a colonizer. The total of all species weighing <5 lbs was approximately 50 lbs. See text for explanation of seed mix numbers. See Appendices A and B for Latin nomenclature if not indicated here.

	Species	**Weight (lbs)**	**Mix No.**
	Shrubs and Small Trees		
	Catclaw	11	2,3
C	*Adenophyllum cooperi*	<5	2,3,4
	Apache plume	4	1,3
	Blackbush	25	2,3,4
C	Black-stem	<5	1,2,4
	Bladder sage	6	1,2,3,4
	Box thorn (*L. andersonii*)	11	1,3
	Boxthorn (*L. cooperi*)	14	1,3
C	Brickellbush	136	1,2,3,4
	Brittlebush	65	1,2,3,4
C	Burrobush	325	1,2,3,4
C	California buckwheat	54	1,2,3,4
C	Cheesebush	80	1,2,3,4
	Cotton thorn	5	1,3
	Creosote bush	420	1,2,3,4
	Desert almond	105	1,2,3,4
	Desert thistle	<5	1,2,4
	Desert willow	<5	1,3,4
C	*Ephedra nevadensis*	34	1,2,3,4
	Ephedra viridis	<5	1,2,4
C	Four-wing saltbush	620	1,2,3,4
	Goldenbush (*E. cooperi*)	76	1,2,3,4
	Goldenbush (*E. cuneata*)		1,3,4
	Goldenhead	18	1,2,3,4
	Green encelia	<5	2,3,4
	Hopsage	3	1
	Interior goldenbush	<5	1,3,4
	Mesquite	23	2,3
	Mojave sage	12	1,3,4
C	Paperflower	152	1,2,3,4
	Parish's viguiera	6	1,3,4
	Pima ratany	<5	1
	Psorothamnus polydenius	6	1

	Species	Weight (lbs)	Mix No.
	Rubber rabbitbrush	125	1,2,3,4
	Salvia	<5	1
C	Sticky snakeweed	670	1,2,3,4
	Turpentine brush		2
	Utah juniper	42	1,2
C	Winterfat	36	1,2,3,4
	Woolly bur-sage	34	1,2,3,4
	Herbaceous Perennials		
C	Apricot mallow	5	1,2,3,4
	Beardtongue		1, 2, 3
C	Canaigre, wild-rhubarb (*Rumex hymenosepalus*)	4	1,2,3,4
	Coyote melon	55	1,2,3,4
	Desert marigold	60	1,2,3,4
C	Desert trumpet		1,3
	Desert milkweed (*Asclepias erosa*)		3
	Four o'clock		1,3
	Freckled milkvetch	<5	3
	Jimson weed	10	1,3,4
C	Mojave aster	11	1,2,3,4
	Owl's clover/paintbrush	5	1,3,4
C	Palmer penstemon	6	1,4
C	Peppergrass (*L. fremontii*)	<5	1
	Prince's plume (*Stanleya pinnata*)		3
	Skunkbrush (*Rhus trilobata*)	3	2
C	*Verbena gooddingii*	<5	1,3
	Wild buckwheat (*E. trichopes*)		1,3,4
	Wire-lettuce		1,3,4
	Succulents		
	Banana yucca	42	1,3,4
	Barrel cactus	28	1,2,3,4
	Beehive cactus	<5	2,3
	Clustered barrel cactus	<5	2,3
	Hedgehog cactus	5	2,3
	Joshua tree	585	1,2,3,4
	Mojave prickly-pear	4	1,4
	Mojave yucca	182	1,2,3,4
	Grasses		
C	Black grama	5	1,2,3,4
	Bluegrass (*Poa secunda*)	<5	1,4
C	Desert needlegrass	42	1,2,3,4
C	Galleta	515	1,2,3,4
	Indian ricegrass	65	1,2,3,4
C	Muhly	200	1,2,3,4
	Sand dropseed	51	1,2,3,4
	Side-oats grama	21	1,3,4
C	Squirreltail	21	1,2,3,4
C	Three-awn	245	1,2,3,4
	Annuals		
	California poppy	<5	3
	Coulter's lupine	<5	1,3,4

Species	Weight (lbs)	Mix No.
Cryptantha circumscissa		1,3,4
Cryptantha nevadensis		1,2,3,4
Cryptantha pterocarya		1,2,3,4
Devil's lettuce		1,3,4
Evening primrose (*Oenothera californica*)		3
Flat-topped buckwheat	7	1,2,3,4
Flax	<5	3
Gilia aliquanta		1,2,3,4
Lacepod, fringepod (*Thysanocarpus curvipes*)		1,3,4
Linanthus demissus	<5	1,3,4
Pectocarya setosa		1,3,4
Phacelia fremontii		1,2,3,4
Phacelia vallis-mortae		1,2,3,4
Plantain (*Plantago patagonica*)		1,2,3,4
Rattlesnake weed (*Chamaesyce albomarginata*)		1,3,4
Sand lupine	<5	1,3,4

Table 10. Seeding rates and methods, CMM, November 2001.

Seeding method	Seeding rate (lbs/acre)	Target seeding area	Mix No.	Acres	Total seed (lbs)
Aerial	15	North dump	1	50.8	762
		South dump (partial)	1	66.3	994.5
		Lesley Ann Dump	1	75.7	1135.5
		Clay pit dump	1	42.2	633
		South dump south face	4	22.9	343.5
		Boneyard North	1	2.8	42
		Total		**260.7**	**3910.5**
	12	North dump road	1	7.6	91.2
		OBHT Pit road	1	2.4	28.8
		Powder magazine area	1	2.1	25.2
		Conveyor belt area (east ½)	1	3.1	37.2
		Total		**15.2**	**182.4**
	10	Jumbo pit (roads, bottom)	2	25.5	255
		OBHT pit (roads, bottom)	2	30.2	302
		South dump, north face	4	16.2	162
		Total		**71.9**	**719**
Manual	20	Crusher area (partial)	3	1.5	30
		Boneyard south	3	2.0	40
		OBHT pit entrance	3	3.6	72
		Roads, banks around contractor shop & office area (partial)	3	3.0	60
		Facilities roads (partial)	3	2.8	56
		Total, Mix #3		**12.9**	**258**
			Seed & Area Totals	**360.7**	**5069.9**

Seed was sifted through a 1 × ½" screen mesh and thoroughly mixed on clean, heavy (60 mil) plastic in the greenhouse. Batches of seed intended for aerial distribution, i.e., Seed Mix Nos. 1, 2, and 4 (Table 9), were uniformly blended and any debris or extraneous plant parts removed in order for the seed to flow evenly through the plane hopper (see aerial methods below). Batches of seed those intended for manual distribution, i.e., Seed Mix No. 3, were also blended to break up clumps, such as that found in three-awn seedheads. All seed was bagged at a standard weight (approximately 30 lbs.) and bags were color-coded according to mix number (11^{th} Report, 2002).

Two methods – aerial and manual – were used. Between the two methods, aerial seeding was generally preferred since it covers greater area in less time and offers more control over and uniformity of seeding rate. In addition, some areas, such as steep slopes that had been graded and/or roughened, were inaccessible by foot or mechanical seeder and required aerial seeding (11^{th} Report, 2002).

Aerial seeding was executed at CMM on November 28, 2001. The plane used was a Rockwell S2R Thrush Commander with a 9-cylinder, 600-hp engine. With its 400-gal hopper and 2-ton payload capacity, the plane was designed for crop-dusting, but held up to 420 lbs of seed mix for the purposes at CMM. The seed was dispersed using a Transland spreader with a variable controlled rate of release. Flight patterns were controlled with geographic positioning system (GPS) instrumentation using a SatLoc guidance system. Weather conditions were ideal: cool, moist, slightly overcast, and wind less than 10 mph. Moreover, the following day brought a light rain/snow mix, which aids in seed retention (11^{th} Report, 2002).

Aerial seeding rates (see Table 10) were calibrated by flying specific patterns over the North overburden area and ground-checking the amount of seed applied. Flight patterns were flown separately over each targeted seeding area at CMM. Prior to seeding each area, their acreages were calculated with AutoCAD and the required weight of seed loaded onto the airplane. Seeding rates were later verified through examination of flat metal surfaces and moist ground surfaces after the seeding operation (11^{th} Report, 2002).

Seed for manual dispersal was loaded into five-gallon buckets. All personnel calibrated their walking/seed dispersal rates before executing the operation in the field. Broadcasting at a rate of approximately twenty pounds per acre (see Table 10) was performed by one to four individuals spaced along lines at regular intervals, depending on the size of the target area. Hand seeding continued through the end of 2001 as small areas became available (11^{th} Report, 2002).

8.15 MISCELLANEOUS OBSERVATIONS

In addition to the formal observations centered on research and reclamation projects as described in Sections 8.0 through 10.0, multiple casual – even anecdotal – observations were made and recorded in the Annual Revegetation Reports as described below.

- **1991**: Transplanted banana and Mojave yuccas were observed to be excellent nurse plants, superior to Joshua tree for revegetation work. Also, four patterns of leaf yellowing of transplanted Joshua trees were described (1^{st} Report, 1992).
- **1992**: Joshua tree had the lowest percentage of individuals among all species salvaged that were deemed to be in excellent health. Joshua tree is particularly sensitive to timing, as a summer transplant is more sensitive than a spring transplant (2^{nd} Report, 1993).
- **Fall 1992**: Three species – apricot mallow, fourwing saltbush, and penstemon – were particularly hardy in establishing from seed on the poor soils at CMM. Apricot mallow is susceptible to grazing, however, necessitating diligent protection from cattle and other herbivores. Fourwing saltbush, in addition to establishing well from seed, serves as an excellent "nurse plant" for other plants such as squirreltail and other grasses. In addition to germinating well from sown seed, penstemon seeds commonly lie dormant for years and are easily released with disturbance such as that incurred by the heavy equipment used in mining operations. With exposure and sufficient water, penstemon readily emerges on poor soils in disturbed areas. Flat-topped buckwheat (skeleton weed) also seeds well into poor-quality sites (2^{nd} Report, 1993).
- **1994**: Peat-based potting mixes do not work well for outplanting (see also Sections 4.2 and 8.10). Plants that were designated for outplanting in the fall of 1994 were held for repotting into a more porous substrate such as calcined clay and/or coarse sand (4^{th} Report, 1995).

9.0 FORMAL RESEARCH REPORTS

All of the papers summarized in the following subsections were published in one or more of the Annual Revegetation Reports beginning with the 2nd Report (1993). Where noted, some papers were presented at conferences or published in peer-reviewed journals. Because many of the projects spanned more than one year, the section is organized chronologically according to year of project initiation.

Despite the proliferation of reclamation and revegetation activity between 1991 and 2001 at CMM (the years reviewed in this research summary; see Section 8.0), only a subset of the associated research was formally summarized and published. Reasons for research not being completed with a formal report include failure of plant survival due to drought, grazing, or trampling; laboratory mishaps; and the departure of personnel.

9.1 BASELINE VEGETATION ANALYSIS (1990-2000)

Because 1990 was the first year of activities at CMM, much of the research was planned and/or initiated during this year and observations were limited. In addition to the baseline vegetation analysis described here, the 1st Report (1992) included in its Appendices the *Soil Survey for the Castle Mountain Project*, Greystone Development Consultants, Inc., November 1989.

The baseline vegetation analysis originally performed in 1990-1991 and reported in the 1st Report (1992) was amended twice as reported in the 5th and 6th Reports (1996 and 1997). The three reports are concatenated and summarized here. Their titles are:

- *Vegetation Analysis, Castle Mountain Project, San Bernardino County, CA.* California Desert Studies Consortium, Fullerton, California, February, 1992 (1st Report, 1992).
- *Vegetation Analysis, 1995: Canonical Discriminant Analysis and Ordination, and Subsequent Application to Community Classification and Initial Geographic Information System Assessments*. R.G. Everett (5th Report, 1996).
- *Castle Mountain Vegetation Analysis, 1996: Aspect and slope field-collected data vs. geographical information system comparisons; and inclusion of aspect and slope as variables in Canonical Discriminant Analysis and ordination*. R.G. Everett (6th Report, 1997).

In addition, all baseline vegetation data were reexamined in 1998 (8th Report, 1999) and an updated analysis conducted in May 2000 (10th Report, 2001). All discussion relevant to the baseline vegetation data and analyses is summarized in this section.

A survey of extant vegetation was conducted by the California State Universities' Desert Studies Consortium during 1990 and 1991 for the Castle Mountain Venture prior to the initiation of surface overburden removal and excavations associated with mining. The objectives of this evaluation were to provide quantitative documentation of the diversity and abundance of plant life at CMM, delineate plant communities, and establish baseline data of undisturbed plant communities at CMM to be used to evaluate future revegetation success in disturbed areas (1st and 5th Reports, 1992 and 1996).

In 1990, the entire property of CMM was subdivided by a grid with lines every 200 m. At each intersection of grid lines a 100-m^2, circular plot (5.64 m radius) was established for a total of 256 plots site-wide. Observations within all plots included aspect, slope, plant community type, perennial species composition and density, and percent cover of grasses. Of these 256 plots, forty-five were randomly selected for more intensive observations of plant coverage and size; species composition and density; perennial plant height, width, and distance from plot center; and intended use (e.g., heap leach pad, mine pit, overburden, historically disturbed, etc.). Annual plants were also surveyed within the forty-five intensive plots, but within a smaller, one-meter-radius plot centered on the grid line intersection (1st Report, 1992).

In 1991, plots in historically disturbed areas and those planned for future disturbance were eliminated from analysis of performance standards. Fifty-six additional intensive plots were established in locations not known to be disturbed, unlikely to support future disturbance, and adjacent to areas that would eventually require revegetation treatment such as the heap leach pad and overburden areas and the Lesley Ann Pit. Resulting from these modifications were a total of 101 intensive plots and 193 non-intensive plots. Sampling procedures followed 1990 protocols (1st Report, 1992).

Most of the plant communities sampled were classified as either Mojave mixed steppe, Joshua tree woodland, or a combination of the two communities. Blackbush scrub comprised 13.6% of the communities sampled. Mojave Desert wash scrub was another community type. Plant species richness in undisturbed areas of CMM ranged from 12.6 to 24.3 species per plot, while perennial plant density in the same areas ranged from 33.6 to 55.2 individuals per plot. Data for these parameters in 1990 and 1991 were "essentially similar" (1st Report, 1992).

On April 23, 1994, the CMM revegetation ecologist met with Rick Everett at the University of California-Riverside, who performed the original baseline vegetation analysis. Dr. Everett was asked to statistically separate the baseline CMM vegetation data into identifiable plant communities and map them (4th Report, 1995).

Clustering of seven plant communities by Canonical Discriminant Analysis (CDA) closely mimicked field vegetation community assignments. Four of the CDA clusters – Joshua tree woodland, desert scrub, blackbush scrub, and desert grassland – can be directly translated to the field. Three CDA clusters represented unusual plant groupings or disturbed areas. Slope and aspect data analyzed with ARC/INFO Geographical Information System software produced conclusions that agreed with field assessments of aerial physiography (5th Report, 1996).

The analysis of the baseline vegetation data performed in 1996 updated the data analysis performed in 1995 as described above. In the paper, Rick Everett clarified his analysis of slope and aspect data in the 5th Report (1996), provided a more detailed methodology for adding new components to his model, and added slope and aspect as components to the model (6th Report, 1997).

In 1998, CMM revegetation personnel reexamined the baseline plant community data in an attempt to best determine how to use it for revegetation purposes. Confusion over interpretation of the data prompted CMM to propose an alternate use for it, and a letter containing this proposal was submitted to regulatory agencies and members of the RRC (8th Report, 1999). In the letter, CMM proposed that changes be made to revegetation plans of CMM based on deficiencies in the original data, and that new baseline vegetation plots replace those established in 1990. The proposal was based on the following rationale (8th Report, 1999):

- Errors and discrepancies in the original data set. It was asserted that the original revegetation plan was based on erroneous field data, particularly that of plant species identification, elevation, slope, and aspect, and inadequate representation of topographic positions. Reclamation requirements for ultimate bond release were to be based on baseline field data (see Section 3.1), and concerns that the data were flawed prompted the greater concern that bond release would not be met if based on inaccurate revegetation models.
- Failure of the revegetation plan to address unknown soil factors. Waste rock piles, pit floors, haul roads, and heap leach piles are composed of fractured, unweathered rock that had been

ripped and covered with a thin layer of salvaged soil or growth media, which has qualities entirely unlike that of undisturbed surrounding areas. Observations of some species colonizing particular substrates better than others should influence the revegetation design of particular areas. For example, blackbush dominated in soils with very low water-holding capacity (WHC) but was absent in soils with high WHC, a relationship independent of slope and aspect (see Section 9.18). This indicates that some data collected for the baseline vegetation analysis is irrelevant to the revegetation process, and other data that were relevant were lacking in the original data.

- Failure of the revegetation plan to address seed availability or the propagation potential of specific plant species. Some plant species, although common in the field, may not be available for revegetation purposes due to limited seed production and/or supplies. This was the case for antelope bush, boxthorn, desert almond, goldenbush, goldenhead, hop-sage, and pima rhatany, for example. Similarly, using nursery-propagated plants for revegetation has limited applications due to the diverse potential among species for nursery-propagation. Antelope bush, burrobush, California buckwheat, desert almond, fourwing saltbush, paper daisy, and salvia all proved to have poor responses to propagation attempts in the greenhouse. Other species such as apricot mallow, banana yucca, barrel cactus, beavertail cactus, burrobush, catclaw, cheesebush, creosote bush, fourwing saltbush, golden cholla, hedgehog cactus, Joshua tree, Mojave prickly pear, Mojave yucca, *Ephedra nevadensis*, sticky snakeweed, viguiera, and winterfat showed particular success in colonizing revegetation sites following seeding or planting. These species – and grasses, importantly (see below) – should be central to revegetation plans for disturbed areas.
- Failure of the revegetation plan to address the importance of grasses. Baseline vegetation data severely underestimated the importance of grasses. As a result, grasses were not emphasized in the original revegetation plan. The fine roots of grasses stabilize soils, thus making them integral to erosion control; grasses are also important for providing organic matter to the soil. A number of perennial grasses native to the area such as black grama, desert needlegrass, galleta grass, Indian ricegrass, muhly, squirreltail, and three-awn should be included in the revegetation plans for all areas at CMM.
- Potential of the revegetation plan for requiring needless costs and diversion of necessary funds from more needed projects. Basing the revegetation of sites on the available baseline data such as [presumably erroneous] slope and aspect and preparing ineffective seed mixes could be a misapplication of funds and other resources. Seed harvesting, irrigation, propaga-

tion, and monitoring and research probably deserve higher priority than the projects emphasized in the original revegetation plan.

The proposed solution to compensate for the deficiencies identified above was to reestablish thirty new vegetation plots in three undisturbed areas adjacent to CMM. Proposed details for the placement and management of these plots were presented in the 8th Report (1999).

An updated baseline vegetation and soils analysis was conducted in May 2000. The earlier baseline vegetation analyses were deemed inconsistent, and many of the original plots could not be located. The California Office of Mine Reclamation (OMR), in cooperation with CMM, used a stratified random sampling method after initially identifying four principal types of vegetation in aerial photographs. These types were (1) low, flat areas ("general"), (2) washes, (3) black bush scrub, and (4) high rocky slopes and ridges. Sample plots were randomly located in each vegetation type. Soils were collected and photographs taken from each plot (10th Report, 2001).

The OMR vegetation analysis identified five vegetation clusters as types and one revegetation cluster; the differences among the terms *vegetation clusters*, *types*, and *revegetation clusters* were not explicated. Although plant species and soil characteristics were used to differentiate clusters, the floral assemblage of each cluster was not entirely unique; that is, there was a high degree of plant species overlap among clusters (10th Report, 2001).

Local soils are generally alkaline, sandy, and low in organics. Amendments of organic matter or other supplements are not generally necessary for native plant growth in most vegetation types (10th Report, 2001).

The recent vegetation analysis presented and discussed the performance criteria for the proposed revegetation standards (Section 3.2). Based on the vegetation analysis, OMR proposed conditions to determine whether the standards had been satisfied for each revegetation area (overburden, leach pad, access roads, and pits). These conditions and recommendations for minimum sampling area, sample plot distribution and size, and number were to be applied during subsequent monitoring for success (10th Report, 2001).

The value of this analysis is in the revegetation strategy proposed specifically for CMM and the conditions specific to this mine site. The strategy is based on the use of local plant species with broad ecological amplitude, or "colonizers". The plants that succeed on mine reclamation sites are a combination of perennial and annual species adapted to disturbance. These are often wash species adapted to fresh soil substrates with periodic flooding requirements. This type of habitat is simulated during reclamation by surface disturbance and water enhancement grading for moisture control. Some species considered to qualify as colonizers, such as creosote bush and Joshua trees, occur throughout CMM and would be expected to grow on most reclaimed areas (10th Report, 2001).

The revegetation strategy also specified target species to be planted or seeded in the four principal vegetation types at CMM. Of note is that the blackbush scrub vegetation type has specific soil requirements that do not occur on disturbed substrates at the mine, and that only narrow strips, such as drill and access roads, would meet the conditions necessary for revegetating washes and blackbush scrub (10th Report, 2001).

9.2 SOIL STOCKPILE QUALITY AT CMM (1992-1994)

R.T.F. MacAller, D.A. Bainbridge, and M.W. Fidelibus

In an effort to determine how to best treat the growth media stockpiles to maximize their VAM inoculum potential, on December 22-23, 1992, SDSU researchers sampled soil from six growth media stockpiles ranging from five to eighteen months in age. Samples were taken from 0-10-, 45-55-, and 90-100-cm depths from the north and south slopes and top of each pile. Soil samples from three unspecified depths were also taken from nearby undisturbed areas corresponding to each pile.

This research utilized the infection unit method (IUM), which counts fungal entry points into plant roots under controlled conditions (2nd Report, 1993). Initial attempts to assess VAM in growth media stockpile soils failed due to contamination with *Rhizopus*, a common bread mold that often infects plant roots and is morphologically similar to VAM. Other observations exclusive of the IUM were made, however, and the growth media piles were resampled in December of 1993 (3rd Report, 1994).

Measurements of soil stockpile soils included available nitrate (NO_3^-), ammonium (NH_4^+), and phosphorus (P). VAM spores were extracted, segregated, and counted. Seeds were also separated and counted (3rd Report, 1994). Results are as follows:

- Contradictory results were reported in the 3rd Report (1994) regarding the relationship between total VAM spore numbers and age of growth media stockpiles. In the main text of the 3rd Report (1994), it was stated that total VAM spore numbers were proportional to the age of the stockpile and moisture content. In the report written by the researchers (in Appendix 4 of the 3rd Report, 1994) as well as the 4th Report (1995), it was stated that the age of the heap had no effect on spore counts or inoculum potential.
- Soil stockpiles have lower inoculum potential than undisturbed areas, but stockpile inoculum potential is still "significant" (4th Report, 1995).
- With the exception of NH_4^+, nutrient levels in the soil stockpiles exceeded those in undisturbed soils (3rd Report, 1994).
- Seeds were "very limited" in the stockpiles and "uncommon" in undisturbed soils. No guidance was given on how to interpret this terminology (3rd Report, 1994).

9.3 HEAP LEACH MATERIAL AS A GROWTH MEDIUM AT CASTLE MOUNTAIN MINE (1993)

MacAller, R.T.F. and D.A. Bainbridge

Because heap leach technology was relatively recent in the early 1990s, little was known about the potential for vegetative growth on heap leach pads following mining. Leaching adds five primary compounds to a heap leach pad: sodium cyanide, sodium hydroxide, cement, lime, and a flocculant. On May 6, 1993, sixteen germinated corn (*Zea mays*) seeds were planted in 10-in^3 containers in one of four substrates:

#1 Rinsed heap leach material with 2.5 cm soil mix of 7:2:1 sand, vermiculite, and potting mix.
#2 Heap leach material with "only a small addition of soil mix (seed spot)." It was unspecified whether the material was rinsed.
#3 Unrinsed heap leach material with a layer of soil mix. The depth of soil mix was unspecified.
#4 Unrinsed heap leach material with a seed spot of soil mix (3rd Report, 1994).

Furthermore, half of each soil treatment was watered with a fertilizer solution (Roots Plus Seedling Starter 2:4:2 NPK) at a ratio of 384:1 fertilizer:water. The other half was provided with water only (3rd Report, 1994).

Results showed that:

- Corn growth was significantly greater in substrate #3 than all other substrates. There were no growth differences between substrates #1 and #4. There was no growth in substrate #2.
- Fertilizer increased growth rates, root and shoot weights, and plant moisture content.
- Root biomass was greater in substrates #3 and #4 than in substrate #1.
- Shoot biomass was greater in substrate #3 than substrate #1.
- Tissue water content was higher in plants grown in substrate #3 than in substrate #1.
- Soil loss was greatest in treatments without soil mix (substrates #2 and #4).

As of January 1994 it had not been determined which of the five additives was most limiting to plant growth (3rd Report, 1994). Experiments on catclaw's growth in heap leach material are described in Section 9.12.

9.4 HEALTH OF PLANTS SALVAGED FOR REVEGETATION AT A MOJAVE DESERT GOLD MINE: YEAR TWO (1993)

R. Franson *in* Roundy, B.A., E.D. McArthur, J.S. Haley, and D.K. Mann; Proceedings: Wildland Shrub and Arid Land Restoration Symposium, 19-21 October 1993, Las Vegas, NV. Gen. Tech Rep. INT-GTR-315, U.S.D.A. Forest Service, Intermountain Research Station, Ogden, UT.

Abstract: At Viceroy Gold's Castle Mountain Mine in the East Mojave Desert, Joshua trees and barrel cacti are salvaged before disturbance and maintained in two nurseries for later outplanting to revegetation sites. The plants are assessed each year on a qualitative scale. In the 1993 survey, 7941 plants were rated. Joshua trees that were salvaged by hand showed only 4% mortality in the nursery each of the first two years. A comparison of Joshua tree health in the two nurseries showed that the Joshua trees in the south nursery had a higher percentage rated as being in poor health. This is attributed to problems with the irrigation system in the south nursery. Barrel cacti had 9% mortality in the first year and 7% mortality in the second year. Barrel cactus plots in undisturbed areas were established in 1993 to compare death rates in the nursery to death rates under natural conditions. Joshua trees and barrel cacti can both be transplanted by bare rooting in large numbers and maintained in nurseries in high densities for at least two years. The data on these nurseries is useful for anyone attempting salvage of *Yuccas* or barrel cacti for restoration or landscaping purposes (4th Report, 1995).

9.5 SOIL PROPERTIES OF PLANT COMMUNITIES AT CMM (1993-1994)

R.T.F. MacAller, D.A. Bainbridge, S. Netto, M.W. Fidelibus, and D.G. Waldecker, 3rd Report, 1994 and R.T.F. MacAller, 4th Report, 1995

The soils of nineteen permanent, undisturbed vegetation plots representing Joshua tree woodland (5 plots), creosote bush/blackbush scrub transition (7 plots), Mojave mixed steppe (2 plots), Mojave Desert wash (3 plots), and juniper (2 plots) communities were sampled for their physical and chemical properties in the spring of 1993. Samples were from 0-10 cm and 10-20 cm. Measurements included nitrate, ammonium, copper, manganese, available phosphorus, calcium, magnesium, sodium, soil moisture, pH, electrical conductivity (EC), saturation percentage, water infiltration, sodium absorption ratio (SAR), and soil compaction as measured with a penetrometer. The two juniper sites were excluded from statistical analysis due to insufficient samples (3rd and 4th Reports, 1994 and 1995).

Results indicated that Mojave Desert wash and Joshua tree communities can be biogeochemically distinguished from the creosote bush/blackbush scrub transition and Mojave mixed steppe communities by their respective concentrations of copper, magnesium, ammonium, soil moisture, phosphorus and calcium (3rd Report, 1994).

The data collected for this study were re-analyzed in 1994 using more sophisticated statistical techniques. These results showed that copper, ammonium, and saturation percentages were different among communities. Also, pH, soil compaction, phosphorus, ammonium, SAR, EC, manganese, sodium, and copper may be the primary factors influencing community “profiles” and of critical influence over species composition. Juniper community soils had higher nutrient concentrations than the other communities (4th Report, 1995).

9.6 REVEGETATION OF OVERBURDEN PILES (1993-1994)

M.W. Fidelibus and D.A. Bainbridge, 3rd and 4th Reports (1994 and 1995).

To help identify factors important to shrub establishment on overburden piles, 278[15] catclaw seedlings were planted on the southeast corner of the South Overburden pile on July 24, 1993, as part of the SDSU Revegetation Research Grant (3rd Report, 1994). Originally, 144 catclaw plants were transported bare-root (with no soil) in “jellyrolls,” and 138 plants in 164-ml “supercells” or pots[16]. Jellyrolling entails extracting plants from their supercells, removing soil from the root mass, placing onto moistened Kimtex™ fabric, and rolling into bundles of 10 individuals.

[15] This number was reported as 289 catclaw seedlings in the 4th Report (1995).
[16] The 4th Report (1995) states that plants were divided equally between jellyroll and supercell treatments.

Jellyrolls were transported to the field in ice-packed coolers. Supercells were transported in shaded racks (3rd Report, 1994).

The experimental area was ripped to a depth of two feet the day before planting. In addition to the jellyroll/no jellyroll treatments, there were four further treatments at the outplanting stage:

1) One liter of stockpiled soil ("growth media") backfilled into the planting holes.
2) Stockpiled soil (growth media) + Tubex™ Treeshelter (Tubex), a translucent section of plastic tubing surrounding each plant and partially buried. Tubex shelters were placed over the seedlings following planting.
3) Tubex with no growth media.
4) Control.

Plants were spaced 0.8 m apart in four rows oriented east-west. There was sufficient space between the second and third rows for a water truck. The top 30 cm of soil was sampled in three locations and tested for available nitrate, ammonium, and phosphorus. Observations of "plant health" (parameters unspecified) on a scale of 0-4 were made two months later in September 1993. Results were as follows:

- Neither Jellyrolling nor transporting in pots conferred any survival benefit.
- Tubex plant shelters increased plant height twofold within the first 2-3 months and benefited plant health.
- Stockpiled soil/growth media added to overburden material appeared to offer no benefit to initial catclaw seedling growth but slightly benefited plant health.
- Overburden nitrate and ammonium concentrations are comparable to those of stockpiled soil, but phosphorus was lower in overburden (3rd Report, 1994).

Cattle grazed these plots in May of 1994 and were only somewhat deterred by barbed wire. However, the majority of the catclaw individuals lived. Observations of plant survival and health were made in June, July, and September of 1994. Results from 1994 indicate that

- Survival of plants shipped in jellyrolls was significantly lower than that of plants shipped in supercells.
- Both the Tubex treeshelters and stockpiled soil/growth media were beneficial to plant survival and growth (4th Report, 1995).

9.7 THE EFFECT OF RECALCITRANT MULCH ON OVERBURDEN MICROBIAL POPULATIONS (1993-1994)

T. Zink

To determine whether bark and straw soil amendments improve the revegetation of mine spoils, twenty-seven 1-m^2 experimental plots were established on the south overburden pile in December 1993. The treatments were:

- Mulch as:
  - 2 cm oat straw (punched into the soil and weighted with rocks)
  - 2 cm pine bark
  - nothing (control)
- Seedling species as:
  - creosote bush
  - Indian ricegrass
  - none (4th Report, 1995).

All seedlings were protected with Tubex™ Treeshelters (see Section 9.6). Soil (top 10 cm) was sampled immediately after plot preparation and again in March and July of 1994. Soil moisture, available and total nitrogen, and bacteria and fungal biomass ratios were analyzed. Seedling survival and growth rates were also measured on the sampling dates (4th Report, 1995).

Results showed that microbial biomass was greater in bark- and straw-amended plots than the control. This was particularly true of the straw amendments. No significant differences were detected among treatments for soil moisture or nitrogen. All seedlings were negatively impacted by drought (and cattle grazing and trampling). Few seedlings survived longer than three months (4th Report, 1995).

9.8 DUSTFALL AT CASTLE MOUNTAIN MINE (1993-1994)

S. Netto and D. Bainbridge

The objective of this study was to gain greater understanding of the quantity and quality of dustfall at sites in and around CMM, to in turn "aid in the management of growth media and mine spoils piles and in the selection of plants for revegetation sites" (4th Report, 1995). To measure dust deposition, an unspecified number of 5-gallon polyethylene buckets were distributed at five locations across the CMM property from July 29th to September 22nd of 1993. Buckets were 37 cm high and 29 cm in diameter, and the bottom of each had two layers of 1.5-cm glass marbles to prevent wind scour. Buckets were secured to the ground by being wired to stakes (3rd and 4th Reports, 1994 and 1995).

Sample locations included three representing intensive activity and disturbance and two in less active, less disturbed areas. The higher disturbance areas were: the southern edge of the South Overburden pile at the top of the slope near the experimental catclaw plot (see Section 9.6), south of the conveyor belt near the primary leach pad, and west of the Lesley Ann Pit near the helipad. The less disturbed areas were: the slope southwest of the administration building, and in the Joshua tree woodland south of the north nursery. Biogeochemical analysis of the dust samples was done at SDSU (4th Report 1995).

Dustfall mass at CMM, in order from greatest to least, was the South Overburden pile, the conveyor belt/leach pad, north nursery, helipad, and the administration building. In general, nutrient concentrations of the dust samples were high enough that dust may be considered a nutrient input to the plant communities at CMM.

9.9 NATIVE SEED COLLECTION, PROCESSING, AND STORAGE FOR REVEGETATION PROJECTS IN THE WESTERN UNITED STATES (1994)

Lippitt, L., M.W. Fidelibus, and D.A. Bainbridge. June 1994. *Restoration Ecology* 2(2):120-131.

Abstract: The foundation of a successful revegetation or restoration program is quality native seed. This requires careful collection, processing, and storage. Mature seed should be collected from healthy, local stands with a sufficiently broad genetic base. Careful identification of the site characteristics and seed-lot tracking are essential. Yearly variation in seed production and seed quality can be very high, and an early determination of seed quality can prevent expensive failures. Nondestructive evaluation using X-rays is effective and economical, but techniques such as staining, inspection, and germination tests can also be helpful. Cleaning, dewinging, and upgrading seed before storage can (1) reduce weight and bulk, (2) improve storage life, (3) increase germination, and (4) make greenhouse production and field planting easier and more economical. The seeds of many native plants can lose their viability quickly if they are not stored under controlled conditions. Seeds in storage must also be protected from rodents, pests, and disease. Dormancy is common in the seeds of many native species, and

experimentation is often necessary to determine the best way to break seed dormancy. This can be complicated by year-to-year and plant-to-plant variation (4th Report, 1995).

9.10 DEFLECTOR SHIELDS (1994)

D.A. Bainbridge, M.W. Fidelibus, and R.T.F. MacAller

Compounding the challenges of a revegetation program in the hot, dry, and windy conditions of CMM are the steep and unstable slopes of overburden piles. In June of 1994, twelve Mojave yucca from the south nursery and twelve Indian ricegrass individuals from the greenhouse were transplanted to the east face of the South Overburden pile. Individuals were 3 m from the top of the slope and 2 m apart. Each individual received 2 ℓ water upon planting. Half of each species were protected from rock fall and erosion by deflector shields constructed from double panels of $^1/_8$-inch corrugated cardboard, stapled to three 1-m-tall wooden stakes (one in the center and one at each end), and folded into a chevron shape. The cardboard panels were 0.25 m at each end and 0.75 m in the middle. Shields were anchored to the overburden slope with the stakes. Individuals received two waterings following planting (4th Report, 1995).

The shelters conferred no effect on health or growth of either species. Researchers did find benefits to their use, however, as planting crews were protected from falling rocks while working and the stakes stabilized the slope while planting holes were dug. Unsurprisingly, the cardboard shelters did not weather well nor withstand the constant bombardment of falling rock (4th Report, 1995).

9.11 OVERBURDEN SEEDING (1994)

D.A. Bainbridge, M.W. Fidelibus, and R.T.F. MacAller

Because the conditions required for seed germination and plant growth are species-specific, researchers studied several microsite treatments to determine which species respond optimally to different conditions. Seed plots were set up in June 1994 on the east slope of the South Overburden pile. There were sixteen treatment combinations testing:

- No seed or seed mix[17].

[17] Apricot globe mallow, boxthorn, buckwheat, catclaw, creosote bush, desert marigold, fourwing saltbush, galleta grass, green encelia, Indian ricegrass, Joshua tree, Mojave aster, Palmer's penstemon, paper daisy, purple three-awn, sideoats grama, winterfat. Proportions were unspecified. (For Latin nomenclature see Appendices A or B).

- Growth media (salvaged from stockpile 3A) to provide nutrients, moisture, decreased temperature, and physical protection.
- A burlap bag ("dirtbag") treatment to hold soil and seeds in place, retain moisture, provide physical protection, and decrease temperature and light intensity. Treatments utilizing the bag contained seed and growth media, if specified, inside the bag, which was secured to the slope with rebar.
- With or without xanthan gum (a "tackifier"), an algal polysaccharide to glue seeds and soil in place, to trap windborne seed, and to retain moisture. Xanthan gum was applied before other treatments.

The plots were surveyed after 60 and 120 days and observations were made on seedling number, type, and density. Precipitation was too low to stimulate any germination; no quantitative results were available as of January 1995 (4th Report, 1995),

9.12 TESTS OF THE ABILITY OF HEAP LEACH MATERIAL TO SUPPORT PLANT GROWTH (1994)

R.T.F. MacAller, R.L. Franson, and D.A. Bainbridge

To investigate the ability of heap leach pads to support plant establishment, two greenhouse studies were designed to examine plant growth potential in heap leach material. Both experiments were conducted at SDSU (4th Report, 1995).

In the first study, growth of blue corn (*Zea mays*) was compared in heap leach material before chemical treatment (sodium cyanide, sodium hydroxide, cement, lime, and flocculant) and in the same material following chemical treatment and rinsing with water. Pre-germinated blue corn plants were planted and the seedlings grown for 30 days in the greenhouse. Results showed plant survival was significantly greater in pre-treatment heap material. In post-treatment heap material, amendments of soil mix (a 7:2:1 ratio of sand, vermiculite, and potting soil) were essential to growth, and fertilizer (Roots Plus Seedling Start [N:P:K ≡ 2:4:2]) improved growth (4th Report, 1995).

The second study compared the growth of catclaw (*Acacia gregii*) among treatments in post-treatment heap leach material. Treatments varied soil amendments (salvaged growth media, overburden, or nothing) and fertilizer (ammonium sulfate, Hoagland's solution, Triple Super Phosphate, or nothing). Pre-germinated catclaw seeds were planted and grown for 60 days in the greenhouse. Results showed that seedling establishment, shoot weight, and plant height were maximized in heap leach material with overburden amendments or nothing at all; further, growth media amendments diminished these parameters. The greatest root weights and extension lengths were observed in material amended with overburden. Fertilizer did not affect any response variable (4th Report, 1995).

9.13 PROTECTION FOR PLANT ESTABLISHMENT ON ARID AND SEMI-ARID SITES (1994)

D.A. Bainbridge for the California Department of Transportation, Desert Plants Project, August 1994

This paper reviewed different methods of protecting young plants from the stressors introduced by herbivory, winds, drought, temperature, and radiation. The different forms of protection evaluated were tree shelters (including Treessentials Supertubes™, Treepee™ shelters, Tree Pro™ shelters, the Tree Sentry™, and Blue-X™ shelters), wire cages and fences for protection from herbivores, rock mulch for protection from climatic extremes and some herbivory, plastic mesh, plant collars, repellents to protect plants from herbivory, dead branches and straw, and shade screens. The more expensive options usually were justified by higher plant survivial (4th Report, 1995).

9.14 CONTAINER TYPES AND SOIL MIXES FOR DESERT RESTORATION (1994)

D.A. Bainbridge, M. Fidelibus, R. MacAller, and M. Darby for the California Department of Transportation, Desert Plants Project, October 1994

This study evaluated different planting containers for desert restoration outplanting projects. The container characteristics reviewed included size, spacing, root growth encouragement and control, temperature, and whether container racks are divided into individual cells. The containers compared included

- supercells (good; under ideal conditions can be very successful)
- plant bands (best, particularly in uncertain environmental conditions)
- newspaper pots (not recommended)
- pipe sections (excellent)
- rolled plastic film tubes (fair)
- block containers (fair)
- peat plugs (untested)
- standard landscaping pots (mixed reviews)

The smallest workable container is often the most effective. Tall pots will usually have excellent survival and rapid growth even in the worst conditions, desirable where fast visual recovery is important. A combination of pot sizes may maximize survival while reducing cost and would provide a range of resilience or survivability and diverse plant architecture with multiple size classes. Tests of soil mixes determined that the best desert soil mix will require as little work as possible; researchers found that using a pumice/sand or pure sand soil may be sufficient for burrobush and creosote bush. Further, inoculation with VAM is recommended for planting on severely disturbed sites (4th Report, 1995).

9.15 THE EFFECT OF CONTAINERLESS TRANSPORT ON DESERT SHRUBS (1994)

M.W. Fidelibus and D.A. Bainbridge. *Tree Planters' Notes* 45(3):82-85, Summer 1994.

The cost of shipping can be reduced if desert shrub seedlings can be removed from containers and transported to the field with roots wrapped in moist fabric "jellyrolls," but desert environments can desiccate exposed roots. In a laboratory experiment performed on burrobush seedlings, no difference was found in moisture potential between seedlings in jellyrolls and those in containers. In a field experiment on catclaw seedlings, no differences were found in survival, health, or growth one year after outplanting between shrubs transported in jellyrolls or containers (5th Report, 1996).

9.16 HERBIVORE EXCLOSURES (1994-1995)

M.W. Fidelibus

To determine the type and degree of protection necessary to ensure plant survival amidst active herbivore (mammal and reptile) populations, an experiment adjacent to the greenhouse was designed to quantify the effects of herbivores of different sizes on seedling survival and seedbank persistence. A 25 × 120-m strip of land was ripped with a tractor to remove weeds and reduce compaction. Eighteen plots measuring 4.75 m^2 were subject to one of six treatments:

- 0.64-cm mesh topped with 6 inches of 15.25-cm aluminum flashing and barbed wire, intended to exclude all herbivores
- 1.25-cm mesh topped with 6 inches of flashing and barbed wire, intended to exclude cows, rabbits, and medium-sized rodents
- 3.8-cm mesh topped with barbed wire, intended to exclude cows and rabbits
- 5-cm mesh topped with barbed wire, intended to exclude cows
- three-sided, 3.8-cm mesh fence topped with flashing (labeled "fence control")
- control (no fence)

In May 1994, a seed mix was raked into the soil at a rate of 55.5 kg/ha. Germination was poor, so in July, Indian ricegrass seedlings were planted in each plot but performed poorly due to drought. In September 1994, eight deer grass (*Muhlenbergia rigens*) seedlings were planted in each plot. As of January of 1995, the seedlings of both species had not grown. Sherman live traps baited with peanut butter were placed in the exclosures to determine whether small mammals penetrated the boundaries. Antelope ground squirrels (*Ammospermophilus leucures*) and kangaroo rats (*Dipodomys deserti*) were able to pass through the “half-inch” (1.25 cm and larger) mesh. The finest mesh (0.64 cm) was impenetrable (4^{th} Report, 1995). In August of 1995, plants in all plots were identified to species and all aboveground material was harvested, dried, and weighed. Results are in Table 11.

Table 11. Species composition of herbivore exclosure plots, August 1995.
Numbers in cells indicate the number of replicates of each treatment (of three total replicates) in which the species or growth form occurred. See Appendices A or B for scientific nomenclature.

	Exclosure structure or mesh size					
Plant species	**Open**	**3-sided**	**3” mesh**	**1½” mesh**	**½” mesh**	**¼” mesh**
Desert marigold	3	3	3	3	3	3
Devil’s lettuce (*Amsinckia tessellata*)	3	3	3	3	3	3
Storksbill, filaree	3	3	3	3	3	3
Assorted dwarf annuals & grasses	3	3	3	3	3	3
Flat-topped buckwheat	3	3	2	2	3	3
Broom snakeweed	3	3	2	2	2	3
Pig-nut, (*Hoffmannseggia glauca*)	1	2	3	3	3	2
Bromus sp.	2	2	2	2	3	2
Galleta grass	1	2	1	2	2	2
Tansy mustard (*Descurainia* sp.)	1	1	2	2	1	2
Palmer penstemon	2	2	1	1	1	2
Winterfat	1	1	1	1	1	2
Fourwing saltbush	1	1	1	1	1	1
Apricot mallow	1	1	1	1	1	1
Three-awn	1	1	1		1	1
Tansy mustard (*Descurainia pinnata*)		1	1	1		2
Desert trumpet	1	1	1		1	1
Astragalus sp.	1			1	1	1
Indian ricegrass			1	1	1	1
Pepper-grass or -wort (*L. fremontii*)		1	1	1	1	
Burrobush	1			1		
Saltbush (*Atriplex* sp.)					1	1
Pepper-grass, -wort (*Lepidium* sp.)						2
Phacelia sp.					1	1
Salsola sp.*			1		1	
Paper daisy					1	
Catclaw					1	
Goldenhead					1	
Ephedra sp.	1					

*was listed as *Salsola iberica*, a species not recognized in this region according to Baldwin et al. 2002

Plant species composition of each plot appeared to have been affected by survival following plot ripping; colonizing plants, presumably from seed; and seed germination. Further, plant biomass was greatest in the two exclosure treatments with the most flashing and smallest mesh and least in the two treatments with the least amount of exclosure (control and fence control); 5th Report, 1996).

Three sizes of live traps were set in all exclosures in October of 1995. Similar to observations made in other months of trap-setting, no rodents penetrated the ¼" mesh (5th Report, 1996).

9.17 SPACING PATTERNS IN MOJAVE DESERT TREES AND SHRUBS (1995)

M. Fidelibus, R. Franson and D. Bainbridge. Pp. 182-4 in Barrow, J.R. *et al.* (eds.), *Proceedings: Shrubland Ecosystem Dynamics in a Changing Environment*. May 23-25, 1996, Las Cruces, NM.

Because planting shrubs at an excessive density or planting incompatible species together may reduce desert revegetation success, a study was designed to determine spacing patterns among the woody perennial species in areas not disturbed by mining activities. Shrub density was 9,000-14,000 individuals/ha. Most were found to be randomly dispersed; however, larger shrubs such as creosote bush and Joshua tree were regularly dispersed and widely spaced. Plants often associated with conspecific neighbors (5th and 6th Reports, 1996 and 1997).

9.18 CHARACTERIZATION OF SOILS AND ANALYSIS OF SOIL AND WATER RELATIONSHIPS FOR SIX STUDY PLOTS ON LOCAL PLANT COMMUNITIES (1998)

R. Poff and T. Cook, March 2, 1999

The objective of this study was to determine whether edaphic (i.e., soil) factors influence the distribution of blackbush in the CMM vicinity. Six study plots representing a range of blackbush dominance were selected from blackbush, mixed desert scrub, juniper woodland/desert scrub, and Joshua tree/desert scrub communities in the vicinity of CMM (scale or radius not specified). The plots ranged in size from 0.2 to 0.8 acres. Soils were sampled at ten points within each of the six study plots and analyzed using standard USDA-National Resource Conservation Service laboratory procedures. Soil organic matter was positively correlated with blackbush density. Other soil chemical properties were within "normal" ranges and did not appear related to blackbush distribution. There was no apparent relationship between blackbush distribution and bedrock type, e.g., rhyolitic or volcanic bedrock or sandy, gravelly, cobbly, or stony alluvium. As blackbush frequency increased, the total number of plant species and percent grass cover decreased. Blackbush frequency was strongly associated with a decrease in plant-available WHC, which is a function of soil depth, rock fragment content, and soil texture. The authors of this study suggested that minespoils soil suitable for establishing a blackbush community should have a total plant-available WHC between 1.0 and 2.0 inches, contain more than 30% rock fragments, be less than 20 inches deep, have a surface gravel mulch, and have organic matter ranging from 1.5 to 2.5 percent (8th Report, 1999).

9.19 EVIDENCE FOR SEVERAL DISTINCT POPULATIONS OF *SALSOLA* IN CALIFORNIA (1998)

Ryan, F.J., D. Bell, and D.R. Ayres, U.S. Department of Agriculture

DNA from two genetic entities representing Russian thistle, Type A and Type B, were isolated. Then their respective random amplified polymorphic DNA (RAPD) profiles were generated using five decameric primers, their genetic distances calculated, and their clustering examined by UPGMA analysis. In addition, each genetic Type was observed for flowering phenology and fruit weight. In combination, results strongly suggest that Types A and B represent two different *Salsola* species (8th Report, 1999).

9.20 ASSESSMENT OF VAM FORMATION IN PLANTS USED FOR REVEGETATION OF MINE SOILS IN SOUTHERN NEVADA AND CALIFORNIA (1998-1999)

B.R. Kropp and D.R. Hansen, Progress and Final Reports (8th & 9th Reports, 1999-2000)

Part I: Seed germination experiments

- Experiment 1: At least twenty seeds of each of twelve desert species were placed on moistened Whatman No. 1 filter paper and incubated at room temperature for 12 days. The species, with germination rates in parentheses, were blackbush (35%), bladder sage (50%), box thorn (0%), California buckwheat (0%), cheesebush (60%), cotton thorn (15%), creosote bush (0%), *Ephedra nevadensis* (also identified as *E. viridis*) (75%), fourwing saltbush (0%), interior goldenbush (35%), *Salvia mojavensis* (50%), and sticky snakeweed (0%) (9th Report, 2000).

- Experiment 2: In order to determine whether unmanipulated mine overburden material was too hard to allow germination, the next experiment compared overburden to overburden mixed with sand as a germination substrate. Species of the seven species that germinated in the test described above were surface-sterilized in 10% chlorine bleach and twenty of each species were planted in each treatment. Results are summarized in Table 12. Results were interpreted to indicate that overburden that had not been mixed with sand was too hard to allow germination (9th Report, 2000).

Table 12. Percent germination of seven species planted in CMM overburden material and overburden mixed with sand.

Species	**% Germination**	
	Overburden	**Overburden + Sand**
Blackbush	0	30
Ephedra sp.	50	55
Interior goldenbush	10	35
Cheesebush	10	25
Bladder sage	0	35
Salvia mojavensis	0	10
Cotton thorn	0	0

- Experiment 3 (Leaching): Fifty seeds of box thorn, California buckwheat, cotton thorn, creosote bush, fourwing saltbush, and sticky snakeweed – the seeds that "did not germinate readily" – were then placed in a nylon stocking which was tied to the end of a faucet. The water was turned on so that it slowly ran through the stocking, washing the seeds continuously for 24 h or longer. Creosote bush seeds germinated during leaching (rates unreported). Seeds were then placed on moistened filter paper and incubated for a few days. Sticky snakeweed and cotton thorn seeds germinated at rates of 16% and 6%, respectively, and these rates were not affected by leaching duration (24 or 72 h). Seeds of both species were susceptible to fungal contamination. Seeds of box thorn, California buckwheat, and fourwing saltbush did not germinate following leaching (9th Report, 2000).

- Experiment 4 (California buckwheat): In addition to the experiments attempted as described above, researchers attempted to germinate the seed of California buckwheat: (1) on moistened filter paper in the dark and (2) with a 16-hour photoperiod and fluctuating day/night temperatures. Because all attempts were unsuccessful, California buckwheat seeds were excluded from further studies (9th Report, 2000).

- Experiment 5 (Box thorn): Two hundred box thorn seeds were sown in a 1:1 mixture of sand and Scot's Redi-Earth. After moistening, the flat containing the seeds was covered with aluminum foil and stratified for 120 days at 4°C. Following stratification the flat was incubated under 26°/16°C daytime/nighttime temperatures and a 16-hour photoperiod for two months. Three of the 200 seeds germinated. Box thorn was excluded from further studies (9th Report, 2000).

- Experiment 6 (Fourwing saltbush): Germination of fourwing saltbush seeds was 8% when 200 seeds were sown in a 1:1 sand:Redi-Earth mix and incubated in the dark at 16°C for one week (9th Report, 2000).

- Experiment 7 (Sticky snakeweed): Approximately 8% germination of sticky snakeweed seeds was observed when sticky snakeweed seeds were sown in a 1:1 sand:Redi-Earth mix and incubated with a 16-hour period and 26°/16°C daytime/nighttime temperatures (9th Report, 2000).

Part II: Growth of desert plants and the role of mycorrhizal fungi

This research had two objectives: to test the viability of the VAM inoculum stored at CMM ("CMM VAM"), and to test the effectiveness of the MycorVam commercial inoculum (Plant Health Care) for inoculating plants native to southern Nevada. Three experiments were executed in the interest of meeting the first objective, as follows (8th Report, 1999):

1) Sweet corn, which was known to form VAM, was used to perform bioassays of varying volumes of inoculum along a dilution curve at 0 (control), 0.5, 1.5, 2.5, 6.5, 13, 26, 66, and 132 ml inoculum per 660-ml pot at five replicates each. MycorVam was used as a "positive control" at 15 ml/pot. Plastic potting containers were washed in chlorine bleach for 10 minutes to eliminate any contaminants inoculum, and 5-6 corn seeds surface-sterilized in 10% chlorine bleach for 15 seconds were planted in the autoclaved sand mixed with inoculum. A thin layer of perlite was spread over the mix to retard evaporation. Plants were watered with Hoagland's nutrient solution modified to contain less phosphorus (PO_4) to encourage mycorrhizae formation. When seedlings were ~5 mm tall (at ~2 weeks) they were thinned to 2-3 per container and grown for another month in the greenhouse. Roots were then harvested, washed, and stored for several weeks in a solution of formalin-aceto-alcohol (FAA, at a ratio of 13 ml formalin:5 ml glacial acetic acid:200 ml ethanol). Roots were stained with lactofuschin according to Kormanik and McGraw (1982), spread uniformly in a glass petri dish containing a few ml of de-staining solution, and examined under a dissecting or compound microscope. Percent colonization was categorized according to the following scale: 0-5%,

6-25%, 26-50%, 51-75%, and 76-100% (Kormanik and McGraw, 1982). No mycorrhizae formed, including the MycorVam samples. The same procedures were performed on wild grass roots, in which mycorrhizae did form. The non-findings were explained with two hypotheses: the phosphorus in the Hoagland's solution, although reduced, was still too high to encourage VAM growth, or the CMM inoculum had become nonviable through storage and the MycorVam was not evenly distributed in the "mix" (8th Report, 1999).

2) This experiment was designed to elucidate the MycorVam results from the above experiment and in support of the second major objective of the CMM VAM research. Corn and sorghum were used as test plants and inoculum amounts were high, at 50% volume. The comparisons were between treatments with and without phosphorus (in Hoagland's solution) and among treatments using MycorVam, no inoculation, and native soil from the Greenville Experimental Farm (considered to be a certain source of VAM). There were ten replicates per treatment and per species. Seeds were surface-sterilized and planted as described above, and incubated for 6 weeks. Roots were harvested and stored in FAA until evaluation of VAM colonization. During root harvest and storage, samples were "accidentally mixed up and mislabeled." Good mycorrhizae formation had occurred but it was not known whether the source was native soil or MycorVam, nor the influence of phosphorus (8th Report, 1999).

The above experiment was repeated with 25% and 5% inoculum and corn only (see below). To achieve a more uniform planting medium, Scott's Redi-Earth planting mix (containing vermiculite and sphagnum moss) was added; inoculum or soil was first mixed with Redi-Earth and moistened with tap water to facilitate mixing. Sand was then mixed in (8th Report, 1999).

Treatment	Planting mix	Watering solution after germination	Percent VAM colonization
25% inoculation	150 ml each MycorVam and Redi-Earth, 300 ml sand	low-PO_4 Hoagland's	trace-25%
		no-PO_4 Hoagland's	trace-50%
Control for 25% inoculation	150 ml each autoclaved MycorVam and Redi-Earth, 300 ml sand	low-PO_4 Hoagland's	0
		no-PO_4 Hoagland's	
5% inoculation	30 ml MycorVam:270 ml Redi-Earth, 300 ml sand	low-PO_4 Hoagland's	trace-25%
		no-PO_4 Hoagland's	trace-25%
Control for 5% inoculation	30 ml autoclaved MycorVam:270 ml Redi-Earth, 300 ml sand	low-PO_4 Hoagland's	0
		no-PO_4 Hoagland's	
Soil control	150 ml each soil and Redi-Earth, 300 ml sand	Tap water	0

There were five replicates of each treatment described above (10 reps of each inoculation level, with half watered with different solutions). Seeds were planted as described above. After about a month of incubation in the greenhouse, roots were harvested, preserved in FAA, and stained as described above. MycorVam manifested as much as 50% colonization during the 6-week growth period. Higher colonization was observed without supplemental phosphorus, although the presence of phosphorus did not entirely inhibit colonization. It was unknown why MycorVam colonized plant roots in this experiment and not in the first experiment described above; researchers hypothesized that it was mixed poorly (8th Report, 1999).

The second major objective of CMM VAM research in 1998 was to assess the effectiveness of MycorVam for inoculating plants native to southern Nevada. An experiment was designed to attempt inoculation of desert plants using mine tailings as a potting substrate and MycorVam or native topsoil as inoculant. Treatments were (a) autoclaved tailings to determine whether the tailings were vulnerable to other fungal contamination, (b) non-autoclaved tailings + MycorVam, (c) non-autoclaved tailings + native soil, and (d) non-autoclaved tailings (see below). Inoculum (MycorVam or soil) treatment levels were 5 and 25%. Nine native species – blackbush, bladder sage, broom snakeweed[18], cheesebush, creosote bush, *Ephedra viridis*, fourwing saltbush, interior goldenbush, and *Salvia mojavensis* – and corn were used as test species. Each treatment was replicated 5 times for each species, for a total of 50 pots per treatment (8th Report, 1999).

Treatment	Tailings (ml)	Inoculum (ml)	Sand (ml)
Autoclaved overburden tailings	2500	0	2500
Non-autoclaved tailings	2500	0	2500
Non-autoclaved tailings + 25% Mycorvam	1250	1250	2500
Non-autoclaved tailings + 5% Mycorvam	2250	250	2500
Non-autoclaved tailings + 25% soil	1250	1250	2500
Non-autoclaved tailings + 5% soil	2250	250	2500

Eight-hundred surface-sterilized fourwing saltbush seeds were sown in a 50/50 mixture of sand and Redi-Earth, incubated in the dark at 15°C, and transplanted after emergence. Eight-hundred snakeweed seeds were treated the same as fourwing saltbush, but incubated in a 16-hour photoperiod and at 26°/16°C daytime/nighttime temperatures. Creosote bush seeds were leached for 5 days before planting. All other seeds were planted directly into containers after

[18] Identified in the 9th Report (2000) as sticky snakeweed (*G. microcephala* as opposed to *G. sarothrae*)

surface sterilization (2-3 minutes in 10% chlorine bleach followed by rinsing with distilled water). The number of seeds per container (between 4 and 20) was determined from their germination percentages. The surface of the planting mix was covered with a thin layer of perlite to retard evaporation; this application for fourwing saltbush and snakeweed was delayed until seedling establishment. All flats were arranged randomly on racks in the greenhouse and watered with tap water for the first three months, after which they were fertilized once a week with Hoagland's solution *sans* PO_4.

Fourwing saltbush, snakeweed, and creosote bush seedlings did not transplant well; most died after one month. Creosote bush was omitted from the study, while fourwing saltbush and snakeweed transplants were incubated under conditions favorable for seed germination and transferred to the greenhouse following emergence. After five months of incubation, most plants were harvested and their aboveground biomass dried to measure dry weight. Some plants were "quite small" and were grown for approximately three more months before harvesting in the same manner. Root staining was performed as described above and roots were examined for VAM according to the 5-class ranking as described above (8th Report, 1999).

Results indicated that VAM formation was higher when soil native to CMM is used as an inoculum. VAM formation in native soil at either 5% or 25% concentrations significantly exceeded that of both MycorVam and overburden material. Interior goldenbush, bladder sage, *Ephedra viridis*, *Salvia mojavensis*, and snakeweed had significantly higher colonization than the remainder of the tested species. Interior goldenbush had significantly higher colonization than bladder sage, and bladder sage in turn had significantly higher colonization than the other species. There were no significant differences among treatments in mean aboveground biomass dry weight (8th Report, 1999).

10.0 OTHER RESEARCH ACTIVITIES

The subsections below describe research output and other activities that occurred in conjunction with the formal research reports described in Section 9.0 such as literature reviews, abstracts submitted to and presentations given at conferences, university course instruction, and published papers.

10.1 1992 (FIRST ANNUAL REVEGETATION REPORT)

Because the 1st Report summarized the first two years of activities at CMM (1990-1991), much of the research was planned and/or initiated during this period and observations were limited. In addition to the baseline vegetation analysis described in Section 9.1, the 1st Report (1992) included in its Appendices the *Soil Survey for the Castle Mountain Project*, Greystone Development Consultants, Inc., November 1989.

10.2 1993 (SECOND ANNUAL REVEGETATION REPORT)

Although three papers were presented in the 2nd Report (1993) as contributions to the CMM revegetation research program, none of them summarized any formal research that had actually occurred at CMM and more accurately constitute literature reviews, as follows:

- *Native seed collection, processing, and storage for revegetation projects* (M.W. Fidelibus and D.A. Bainbridge). See Section 9.9 for the abstract of this paper, which was published in *Restoration Ecology*, June 1994.
- *Disease and pest management for a desert container nursery* (K. Conners and D.A. Bainbridge). This paper advocates the use of integrated pest management (IPM) for controlling diseases in nurseries. IPM integrates economic, ecological, and sociological factors into a management program. Sanitation is essential to disease prevention. Accurate identification of disease is also important.
- *Pitting to improve native seed establishment* (D.A. Bainbridge and V.M. Rorive). Making small basins or pits on the soil surface is a low-cost method of treating large areas of degraded desert. A large tractor and 25-foot pitting disk can treat 125 acres in a day. Seeding following pitting is recommended for areas with little residual seed source such as barren soils. Additions of compost, mulch, organic matter, fertilizer, and/or transplants may enhance revegetation.

In addition, the CMM revegetation ecologist submitted the following two abstracts:

- *Health of plants and topsoil salvaged for revegetation at a Mojave Desert gold mine*. R.L. Franson, G.A. Gernath, and L.A. Pirozzoli. Presented May 1993 to the 10th national meeting of the American Society for Surface Mining and Reclamation (ASSMR) (3rd Report, 1994).
- *Health of plants and soil salvaged for revegetation at a Mojave Desert gold mine*. R.L. Franson and G. Bernath. Presented October 1993 to the 8th Wildland Shrub and Arid Land Restoration Symposium (WSALRS) (3rd Report, 1994).

The CMM revegetation ecologist also submitted the paper *Health of plants and soil salvaged for revegetation at a Mojave Desert gold mine* (R.L. Franson and G. Bernath) to the Proceedings of the ASSMR (2nd Report, 1993).

10.3 **1994 (THIRD ANNUAL REVEGETATION REPORT)**

In addition to the research papers summarized above in Sections 9.2, 9.3, 9.6, and 9.6, the CMM revegetation ecologist gave four presentations in 1993, those described in Section 10.2, and the two below:

- *A unique revegetation program at a Mojave Desert gold mine*. R. Franson, Revegetation and Reclamation Training Workshop, National Park Service, April 1993.
- *A unique revegetation program at a Mojave Desert gold mine*. R. Franson, D. Bainbridge, and G. Bernath, 5th Annual Conference of the Society for Ecological Restoration (SER), June 1993 (4th Report, 1995).

The CMM revegetation ecologist was also an instructor for the October 1993 Desert Restoration Workshop sponsored by the SER, and published the paper *Unique revegetation program at Mojave Desert gold mine eases environmental concern (California)* (R. Franson) in Restoration and Management Notes 11(2):179-180 (4th Report, 1995).

10.4 **1995 (FOURTH ANNUAL REVEGETATION REPORT)**

In addition to the research papers summarized above in Sections 9.1, 9.2, 9.4 - 9.14, and 9.16, the CMM revegetation ecologist in 1994 gave six invited presentations. Four abstracts for volunteered talks or posters at meetings were produced in 1994:

- *An exclusion experiment to quantify herbivory in the Mojave Desert*. R.L. Franson, M. Fidelibus, M. Heim and D. Bainbridge. Presentation, SER California Chapter Annual Meeting, May 1994.

- *Application of the infection unit method to evaluate VAM fungal infectivity of topsoil during storage.* R. Franson, M. Darby, M. Fidelibus and D. Bainbridge. Presentation, 6th Annual Meeting, SER, August 1994.
- *Revegetation of overburden at a Mojave desert gold mine.* M. Fidelibus, D. Bainbridge, and R.L. Franson. Poster, 6th Annual Meeting, SER, August 1994.
- *Plant/soil relations of reference sites to improve gold mine restoration*. R.T.F. MacAller, D. Bainbridge, D. Waldecker and R.L. Franson. Poster, 6th Annual Meeting, SER, August 1994.

Also published were

- Franson, R. 1994. The management of greenhouse and transplant nurseries to improve revegetation success at a Mojave Desert gold mine. Pp. 100-101 *in* Proceedings of the Mining Environmental Management Conference, October 1994, Reno, NV.
- M.W. Fidelibus. 1994. Jellyrolls reduce outplanting costs in arid land restoration (California), *Restoration and Management Notes* 12(1).
- D.A. Bainbridge and M.W. Fidelibus. 1994. Treeshelters improve woody transplant survival on arid lands (California), *Restoration and Management Notes* 12(1).

10.5 **1996 (FIFTH ANNUAL REVEGETATION REPORT)**

In addition to the studies summarized in Sections 9.15 and 9.17, publications by the CMM revegetation ecologist in 1995 included the following:

- D. Bainbridge, R. Franson, C.A. Williams, L. Lippitt, R. MacAller, and M. Fidelibus. 1995. A Beginner's Guide to Desert Restoration. USDI, National Park Service, Denver Service Center.
- R. Franson. 1995. A Dichotomous Key for Selecting Plant Material for Restoration Projects.
- Franson, R.L. 1993. Health of plants salvaged for revegetation at a Mojave Desert gold mine. Pp. 78-80 *in* Roundy, B.A., E.D. McArthur, J.S. Haley, and D.K. Mann, comps. Proceedings: Wildland Shrub and Arid Land Restoration Symposium; 1993 October 19-21; Las Vegas, NV. Gen. Tech. Rep. INT-Gtr-315, Ogden, UT: USDA Forest Service, Intermountain Research Station.
- R.G. Everett. 1995. *Vegetation Analysis, 1995: Canonical Discriminant Analysis and Ordination, and Subsequent Application to Community Classification and Initial Geographic Information System Assessments*. See Section 9.1 for a summary of this research.

In addition, seven abstracts were submitted for four meetings in 1995.

- *Spacing patterns in Mojave Desert trees and shrubs*. M.W. Fidelibus, R.L. Franson, and D.A. Bainbridge, 9th Wildland Shrub Symposium, May 23-25, Las Cruces, NM.
- *Tests of the ability of heap leach materials to support plant growth*. R.T.F. MacAller, R.L. Franson and D.A. Bainbridge, 12th Annual Meeting, American Society for Surface Mining and Reclamation, June 3-8, Gillette, WY.
- *Long-term data on* Yucca *and barrel cactus salvage for revegetation at a California gold mine*. R. Franson, 4th Annual Meeting, SER, California Chapter, Sept 8-9, Boulder Creek, CA.
- *What a restorationist needs to know about plant population genetics or: A common-sense approach to selecting plant materials for restoration projects.* R.L. Franson, SER International Conference, Sept 14-16, Seattle, WA.
- *Examining soil properties of vegetation for gold mine restoration*. R.T. MacAller and R. Franson. *Ibid.*
- *Comparison of manual and mechanized techniques for gold mine revegetation.* M.W. Fidelibus, R. Franson, and D.A. Bainbridge. *Ibid.*
- *Practical use of VAM fungi in arid land mine revegetation.* M.W. Fidelibus, M. Darby, R. Franson and D.A. Bainbridge. *Ibid.*

The CMM revegetation ecologist gave three invited presentations in 1995:

- *When ecologists don't work in academia; the revegetation program at Castle Mountain Mine*. April 28, Department of Biology, California State University – San Bernardino.
- *Greenhouses and nurseries at a desert gold mine*. October 14, Southern California Botanists, 21st Annual Symposium, Fullerton, CA.
- Opening talk, round table on Marketing Restoration, Nov 15-16, Desert Lands Rehabilitation Workshop.

10.6 **1997 (SIXTH ANNUAL REVEGETATION REPORT)**

In addition to the research papers summarized in Section 9.17, the CMM revegetation ecologist in 1996 submitted two abstracts for annual meetings of SER:

- *Long-term data on* Yucca *sp. and barrel cacti salvaged for revegetation at a California gold mine*. R.L. Franson and S. Plath. Presentation, 5th Annual Meeting, SER, California Chapter, Oct-Nov 1996.
- Poster, SER, June 1996 [no title or author specified]

Four presentations by the CMM revegetation ecologist were invited:

- Mojave Native Plant Society, March 21, 1996, Las Vegas, NV [no title specified]
- San Gabriel Valley Cactus and Succulent Society, May 19, 1996 [no title or location specified]
- San Diego Cactus and Succulent Society, July 13, 1996 [no title or location specified]
- *Revegetation of native grasses at a Mojave Desert gold mine.* R. Franson and S. Plath, Future of Arid Grasslands Conference, Oct 9-13, Tucson, AZ.

Submitted to *Restoration and Management Notes* was *A Dichotomous Key for Selecting Plant Material for Restoration Projects* (R.L. Franson).

Drafted was the second edition of *Beginner's Guide to Desert Restoration* for the Interagency Desert Restoration Task Force.

11.0 MONITORING

Monitoring of the revegetation areas is critical to determining the success of the research and reclamation programs at CMM and whether success criteria will be met. Evaluating the effectiveness of revegetation methods began in 1998 and will continued through 2002. Monitoring began in 2002 and will continue for 10 years, or until the CMM has met all revegetation requirements (see Section 3.2). Although monitoring continues at CMM, only the first two monitoring reports are summarized here. Additional monitoring information can readily be obtained upon request.

11.1 TRANSPLANTS

Transplanting (or "outplanting") is generally considered as a way to increase plant diversity and insure the presence of target species. However, it is an expensive, labor-intensive method of revegetation with the plants requiring long-term individual handling and care with planting techniques. The plants come from two sources: 1) salvaged from areas to be disturbed and transplanted to a nursery or directly to revegetation areas, or 2) propagated from seed or cuttings in the greenhouse or nursery. Propagated plants require watering while in the greenhouse or nursery and generally require supplemental watering after being transplanted to the revegetation areas (10th Report, 2001).

In 1998, CMM surveyed all transplanted yuccas in Revegetation Areas 1-3 as well as the nursery. The health of the plants was categorized (good, poor, or dead) and cross-referenced to their transplant methods (bare root, boxed, or potted). In the revegetation areas, only one individual of Mojave yucca was containerized in a box, pot, or burlap; all others were transplanted with bare roots. Thus, no conclusions could be drawn about the effectiveness of different transplant methods with respect to this species. Further results from 1998 and 1999 monitoring are in Table 13. Observations of Joshua tree performance in the Revegetation Areas corresponded to those in the nursery (Table 13), suggesting that seed-grown plants – and possibly spaded trees pending more observations – may have better survival rates in reclamation efforts (8th Report, 1999).

In response to the observations of transplanted *Yucca* species made in 1998, the "*Yucca* health project," designed to measure the health of transplanted Joshua trees and Mojave yucca throughout CMM, was formally initiated in 1999. In addition to the data in Table 13, containerized Joshua tree transplants in 1999 performed much better than bare-root transplants, with no increased mortality between 1998 and 1999 and an increase in health from poor to good observed in four individuals (9th Report, 2000).

Table 13. Results from the 1998-1999 *Yucca* health monitoring project. Missing data were not reported.

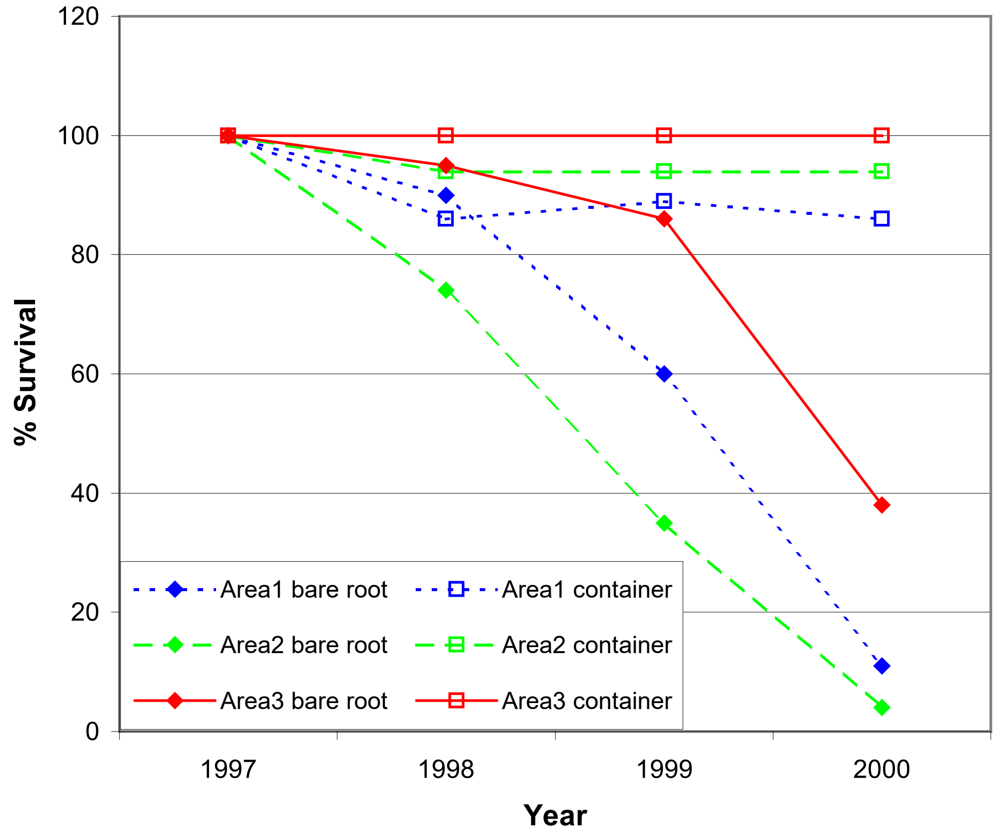
Species	Location	Transplant Method	1998 Condition (%)			1999 Condition (%)		
			Good	Poor	Dead	Good	Poor	Dead
Mojave yucca	Revegetation Areas	Bare root	44		22	32		36
	Nursery	Bare root	70% "survival"					
Joshua tree	Revegetation Areas	Containerized	78					
		Bare root*	19†	62	17	9		52

* Results in the nursery were similar
† This value reported as 21% in the Ninth Report (2000).

By the year 2000, trends of transplanted Joshua tree survival at CMM were becoming apparent. A comparison of Joshua trees transplanted with bare roots versus containers indicated higher survival of containerized plants in Revegetation Areas 1-3 (Figure 4). The plants surveyed were transplanted directly into revegetation areas on the South Overburden from the salvage areas. After three years, survival of the containerized trees was 86% or better, while that of bare-rooted trees was 38% or worse. It was determined that future salvage of Joshua trees would be with a tree spade whenever possible depending on access and topography (10th Report, 2001).

Transplant success in Revegetation Area 8A on the South Overburden during 1999 and 2000 ranged from 31 to 62% depending on plant species and location (Table 14). The drill roads had the highest survival rates (average of 62%), but only four species and the lowest total number of plants were transplanted to these areas. Section 1 supported twenty species, only nine of which had a survival rate of over 50% after a single year. Section 2 had the poorest overall survival rate at 31% with only five of the fourteen species surviving at rates of over 50%. In general, the most successful transplanted species were the succulents, which have shallow, fibrous root systems and water storage organs within their stems (10th Report, 2001).

Figure 4. Survival rates of salvaged and transplanted Joshua trees, 1997-2000.



11.2 Plant Density and Diversity

In 1998, CMM established twelve 144-ft^2 permanent plots intended for annual surveys in three areas of Revegetation Area 3. Before surveying, all Russian thistle was removed. All plants in each plot were identified according to species and counted. See Table 15 for data. Across all plots, *Ephedra nevadensis* comprised 40%, desert marigold 19.6%, and cheesebush 10.2% of the young plant community. *Encelia* sp. and Palmer penstemon had voluntarily established from an outside seed source. Diversity ranged from 2 to 12 plants per plot, while density ranged from 112 to 1772 plants/100 m^2 (8th Report, 1999).

Initiated in 1999 was a documentation of density and diversity measured in permanent plots in each Revegetation Area. In addition to the twelve plots established in 1998 in Area 3 of the South Overburden for this purpose, an additional twelve plots were established in Areas 1, 4, 5, 6, and 7 in 1999. Results from these monitoring efforts are summarized in Table 15.

Table 14. Area 8A transplanted shrub monitoring results.

Plant species	Section 1			Section 2			Drill roads		
	total	live	% live	total	live	% live	total	live	% live
Banana yucca	--	1	--	6	2	33	--	--	--
Barrel cactus	6	0	0	--	--	--	30	30	100
Beardtongue	6	0	0	--	--	--	--	--	--
Beavertail cactus	10	0	0	10	9	90	--	--	--
Bladder sage	27	1	4	41	3	7	--	--	--
Catclaw	2	0	0	--	--	--	--	--	--
Cheesebush	32	19	59	77	21	27	--	--	--
Clustered barrel cactus	3	0	0	--	--	--	--	--	--
Cotton thorn	24	0	0	64	0	0	--	--	--
Creosote bush	37	33	89	76	72	95	24	13	54
Ephedra nevadensis	31	24	77	69	20	29	27	13	48
Golden cholla	12	13	108	25	28	112	--	--	--
Hedgehog cactus	16	13	81	18	1	6	--	--	--
Hop-sage	13	0	0	--	--	--	--	--	--
Mojave aster	16	1	6	64	1	2	--	--	--
Mojave prickly-pear	16	16	100	25	20	80	--	--	--
Mojave yucca	--	1	--	5	3	60	--	--	--
Opuntia parryi	12	12	100	--	--	--	--	--	--
Palmer penstemon	15	1	7	32	1	3	--	--	--
Pancake prickly-pear	4	3	75	--	--	--	--	--	--
Three-awn	47	7	15	90	7	8	60	31	52
Winterfat	16	13	81	--	--	--	--	--	--
Total	**345**	**156**	**45**	**602**	**188**	**31**	**141**	**87**	**62%**

Observations from 1999 indicated that seeding rates for fourwing saltbush and *Ephedra nevadensis*, which dominated the revegetation areas in this monitoring period, needed to be reduced and that “natural” overburden material appeared to be a good seedbed substrate (9th Report, 2000). Monitoring of the twelve plots on Revegetation Areas 1, 4, 5, 6, and 7 was again executed in 2000 (Table 15, Appendix C). The reason for the poor revegetation on Area 4 was not understood but was hypothesized to be related to the time of seeding with high winds and poor rains. The two species present in Area 4, fourwing saltbush and barrel cactus, were both transplanted (10th Report, 2001).

Table 15. Plant density and diversity results from monitoring, South Overburden, CMM.
Plots in Revegetation Areas 1, 4, 5, 6, and 7 were not established until 1999. Missing data were not reported or summarized. Additional details for 2000 are in Appendix C.

Revegetation Area #	No. plots	Plot size (m^2)	Avg. density (plants/100 m^2)				Diversity (no. spp. in all plots)				Notes
			1998	1999	2000	2001	1998	1999	2000	2001	
1	3	25	480	416[a]	428	449		13[b]	18[c]	12	Indian ricegrass most abundant sp., 1999
3	12	13.4	483*	349*		377	8*	8*		8	Cattle invasion (§ 8.8.5) presumed to depress 1999 density & diversity values.
4	2	25		14	20	18		2	2	2	Treated identically except that Area 4 covered w/ growth media before seeding & transplanting. Area 4 had greatest cover of undesirables among all Reveg. Areas, 2001.
5	2	25		448*	452	560		10	12[d]	11	
6	3	25		560	548	511		11[e]	15[f]	11	
7	2	25		804	904	936		10[g]	17[h]	12	Silver wormwood not in seed mix. Growth media not stockpiled but transported directly from Hart Tunnel Haul Rd.

[a-h] 11th Report (2002) stated values to be (a) 403, (b) 10, (c) 11, (d) 10, (e) 9, (f) 11, (g) 9, (h) 14
* from 11th Report (2002)

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APPENDIX A

Naturally-occurring plant species observed at Castle Mountain Mine, 1990-2004. These species were not seeded in or otherwise artificially introduced.

COMMON NAME	SCIENTIFIC NAME
Shrubs/Trees	
Blackbush	*Coleogyne ramosissima*
Black-stem	*Chrysothamnus paniculatus*
Bladder sage	*Salazaria mexicana*
Brickellbush	*Brickellia incana*
Brittlebush/incienso	*Encelia farinosa*
Box thorn, wolfberry	*Lycium cooperi*
Broom snakeweed	*Gutierrezia sarothrae*
Burrobush	*Ambrosia dumosa*
California buckwheat	*Eriogonum fasciculatum*
Catclaw	*Acacia greggii*
Cheesebush	*Hymenoclea salsola*
Cotton thorn, felt thorn, or horse-	*Tetradymia stenolepis*
Creosote bush	*Larrea tridentata*
Desert willow	*Chilopsis linearis*
Four o'clock	*Mirabilis multiflora*
Four-wing saltbush	*Atriplex canescens*
Goldenbush	*Ericameria cooperi*
Goldenhead	*Acamptopappus sphaeroceph-*
Green or Virgin River encelia	*Encelia virginensis*
Hop-sage	*Grayia spinosa*
Interior goldenbush	*Ericameria linearifolia*
Mormon tea	*Ephedra virdis*
Parish's viguiera	*Viguiera parishii*
Peppergrass	*Lepidium fremontii*
Pima rhatany / purple heather	*Krameria erecta*

COMMON NAME	SCIENTIFIC NAME
Shrubs/Trees (ctd.)	
Rubber rabbitbrush	*Chrysothamnus nauseosus*
Salvia	*Salvia dorrii*
Senna	*Senna* sp.
Shadscale or saltbush	*Atriplex confertifolia*
Shrubby encelia	*Encelia frutescens*
Sticky snakeweed	*Gutierrezia microcephala*
Utah juniper	*Juniperus osteosperma*
Viguiera	*Viguiera deltoidea*
Winterfat	*Krascheninnikovia lanata*
Wire-lettuce	*Stephanomeria pauciflora*
Woolly bur-sage	*Ambrosia eriocentra*
Yellow encelia	*Encelia actoni*
Perennial Forbs	
Apricot (globe) mallow	*Sphaeralcea ambigua*
Beardtongue	*Penstemon bicolor*
Beardtongue (Palmer penstemon)	*Penstemon palmeri*
Coyote melon	*Cucurbita palmata*
Desert marigold	*Baileya multiradiata*
Desert paintbrush	*Castilleja angustifolia*
Desert thistle	*Cirsium neomexicanum*
Mojave aster	*Xylorhiza tortifolia*
Paper daisy	*Psilostrophe cooperi*
Phacelia	*Phacelia* sp.
Silver wormwood	*Artemisia ludoviciana*
Stephen's beardtongue	*Penstemon stephensii*

COMMON NAME	SCIENTIFIC NAME
Perennial Succulents	
Banana (blue) yucca	*Yucca baccata*
Barrel cactus	*Ferocactus cylindraceus*
Beavertail cactus	*Opuntia basilaris*
Beehive cactus	*Escobaria vivipara*
Club/mat cholla	*Opuntia parishii*
Clustered barrel (cottontop) cactus	*Echinocactus polycephalus*
Golden cholla	*Opuntia acanthocarpa*
Hedgehog cactus	*Echinocereus engelmannii*
	Echinocereus triglochidiatus
Joshua tree	*Yucca brevifolia*
Mojave prickly-pear	*Opuntia erinacea*
Mojave yucca	*Yucca schidigera*
Nipple/fish-hook cactus	*Mammillaria tetrancistra*
Pancake prickly-pear	*Opuntia chlorotica*
Silver cholla	*Opuntia echinocarpa*
Perennial Grasses	
Desert needlegrass	*Achnatherum speciosum*
Black grama	*Bouteloua eriopoda*
Fluffgrass	*Erioneuron pulchellum*
Galleta grass	*Pleuraphis jamesii*

COMMON NAME	SCIENTIFIC NAME
Perennial Grasses (ctd.)	
Indian ricegrass	*Achnatherum hymenoides*
Mesa dropseed	*Sporobolus flexuosus*
Muhly	*Muhlenbergia porteri*
Side-oats grama	*Bouteloua curtipendula*
Squirreltail	*Elymus elymoides*
Annual Forbs	
California poppy	*Eschscholzia californica*
Flat-topped buckwheat/skeleton	*Eriogonum deflexum*
Desert trumpet	*Eriogonum inflatum*
Jimson weed	*Datura wrightii*
Peppergrass, pepperwort	*Lepidium lasiocarpum*
	L. fremontii
Whisk broom	*Eriogonum nidularium*
Annual Grass	
Six-week fescue	*Vulpia octoflora*
Introduced/Exotic	
Cheatgrass	*Bromus tectorum*
Goosefoot	*Chenopodium incanum*
Russian thistle	*Salsola tragus (paulsenii)*
Storksbill, filaree	*Erodium cicutarium*

APPENDIX B

Species from which seed was collected by year in the Castle Mountain Mine vicinity (see Section 7.0). See Appendix A for Latin nomenclature if not indicated here.

Plant Species	Year										
	1991	1992[b]	1993	1994	1995[c]	1996	1997	1998	1999	2000[d]	2001[e]
Adenophyllum cooperi					X						
Apricot mallow			X		X		X				
Apache plume (*Fallugia paradoxa*)								X			
Banana yucca			X		X		X	X			
Barberry (*Berberis haematocarpa*)				X							
Barrel cactus					X						
Beardtongue/Palmer penstemon			X	X	X				X		
Beavertail cactus (*Opuntia basiliaris*)				X							
Big galleta (*Pleuraphis rigida*)									X	X	
Bladder sage				X				X			
Blackbush					X			X			
Black grama								X			
Black-stem					X		X		X	X	
Blue grama (*Bouteloua gracilis*)									X		
Box thorn/Wolfberry			X	X	X			X			
Brickellbush			X				X		X	X	
Brickellbush (*B. oblongifolia*)				X							
Brittlebush/incienso					X		X				
Burrobush			X	X	X		X	X		X	
California buckwheat			X	X	X			X		X	
California poppy					X						
Castilleja (paintbrush) sp.							X				
Catclaw		X	X	X							
Cheesebush					X			X		X	
Cottonthorn		X		X	X			X			
Cottontop cactus					X						
Coulter's lupine (*Lupinus sparsiflorus*)			X								
Coyote melon				X			X		X	X	
Creosote bush	X	X	X	X	X		X	X	X		
Desert almond (*Prunus fasciculata*)					X					X	
Desert marigold	X		X	X	X			X	X	X	
Desert needlegrass					X		X	X	X		

Plant Species	Year										
	1991	1992[b]	1993	1994	1995[c]	1996	1997	1998	1999	2000[d]	2001[e]
Desert paintbrush					X						
Desert thistle					X		X		X		
Desert trumpet		X									
Desert willow		X		X			X				
Encelia					X						
Ephedra nevadensis										X	
Flax (*Linum lewisii*)			X				X		X		
Four o'clock		X			X		X				
Fourwing saltbush	X	X	X	X	X	X	X	X			
Foxtail chess (*Bromus madritensis* ssp. *rubens*)[a]			X								
Freckled milkvetch (*Astragalus lentiginosus*)								X			
Galleta grass	X		X	X	X	X	X	X	X		
Goldenbush (*E. cooperi*)								X			
Goldenbush (*E. cuneata*)							X				
Goldenhead					X		X	X			
Grama (*Bouteloua* sp.)										X	
Green encelia	X		X	X				X			
Haplopappus sp. (Asteraceae)				X							
Hedgehog cactus			X		X		X				
Hop-sage					X			X			
Horehound (*Marrubium vulgare*)			X								
Indian ricegrass					X			X	X	X	
Interior goldenbush					X		X	X			
Jimson weed				X	X		X				
Joshua tree				X	X		X			X	
Mesa dropseed								X			
Mesquite/Honey mesquite (*Prosopis glandulosa*)				X							
Mojave aster			X		X		X	X			
Mojave prickly pear			X	X							
Mojave sage (*Salvia mohavensis*)					X		X				
Mojave yucca				X	X		X			X	
Mormon tea					X		X				
Muhly	X				X	X	X	X		X	
Paintbrush or owl's clover (*Castilleja linariifolia*)					X						
Pancake prickly pear					X						
Paper daisy			X	X	X				X		

Plant Species	Year										
	1991	1992[b]	1993	1994	1995[c]	1996	1997	1998	1999	2000[d]	2001[e]
Penstemon bicolor			X	X	X						
Peppergrass or pepperwort (*L. fremontii*)					X		X	X			
Phacelia		X									
Phacelia crenulata									X		
Pima rhatany							X	X			
Purple three-awn	X		X	X							
Rabbitbrush (*Chrysothamnus teretifolius*)					X						
Rubber rabbitbrush		X		X		X	X	X			
Salvia					X		X	X			
Sand dropseed (*Sporobolus cryptandrus*)									X		
Sand lupine (*Lupinus brevicaulis*)					X						
Senna		X									
Side-oats grama	X								X		
Single-leaf pinyon pine (*Pinus monophylla*)							X				
Six-week fescue									X		
Squirreltail (*Elymus elymoides*)			X		X				X		
Spike dropseed (*Sporobolus contractus*)										X	
Stephen's beardtongue		X									
Sticky snakeweed				X				X	X	X	
Three-awn (*Aristida purpurea*)					X				X	X	
Three-awn (*Aristida* sp.)										X	
Turpentine-brush (*Ericameria laricifolia*)									X		
Utah juniper		X		X							
Verbena gooddingii				X							
Viguiera sp.					X						
Viguiera deltoidea	X			X			X				
Winterfat			X					X	X		
Woolly bur-sage								X	X	X	
Total number of species	**9**	**12**	**25**	**32**	**48**	**4**	**33**	**32**	**24**	**20**	
Mass collected (lbs)			**2165**	**693**	**2131+**	**143.5**	**416.3**	**2818**	**2847.5**	**2185**	**1150**

[a] This nonnative species was collected due to its exceptional colonizing ability. Authors stated that it was not likely to be used (3rd Report, 1994).

[b] In addition to the species indicated in Appendix B, two unidentifiable Asteraceae species were also collected in 1992 (2nd Report, 1993).

[c] In addition to the species indicated in Appendix B, less than two pounds were collected of desert needlegrass, Apache plume, barrel cactus, four o'clock, bladder sage, and galleta grass in 1995 (5th Report, 1996).

[d] Seed collected by Desert Enterprises (Morristown, AZ).

[e] Species not specified.

APPENDIX C

Numbers of plants in plots on South Overburden Plots at CMM, 2000 (see Sections 8.8 and 11.2). A blank indicates that no individuals of that species were observed. See Appendix A for Latin nomenclature.

Revegetation Area	**1**			**4**		**5**		**6**			**7**	
Plot number	**1**	**2**	**3**	**1**	**2**	**1**	**2**	**1**	**2**	**3**	**1**	**2**
Apricot mallow	21	2	15					9	6	11	19	11
Barrel cactus				3	3	1	2		1			
Black grama											8	
Boxthorn (*L. andersonii*)									2			
Burrobush		4				7	3	10	10	7	6	7
California buckwheat	1	2					1	1	12	1		1
Cheesebush		5				1			1		3	6
Creosote bush	7	11	14			12	28	9	5	1	28	39
Desert marigold	11	29	9			54	21	41	16	32	94	108
Encelia sp.	9	4	12			9		19	13	17	3	14
Ephedra nevadensis	1	14				2	4		13	6	1	
Fluffgrass	1											
Fourwing saltbush	3	17	8	1	3	20	16	15	8	25	48	36
Goldenhead								1				
Green encelia							7					
Indian ricegrass	56	1	45								2	2
Interior goldenbush			1									
Joshua tree											1	
Mojave aster	3	5	2			12	9	24	49	25	1	
Muhly								4		3		
Paper daisy		3										
Silver wormwood												1
Sticky snakeweed			1								2	4
Three-awn		3				1	16	9		5	4	2
Verbena gooddingii												1
Winterfat			1									
Wire-lettuce	1											
Total plant individuals	**114**	**100**	**108**	**4**	**6**	**119**	**107**	**142**	**136**	**133**	**220**	**232**
No. species	**11**	**13**	**10**	**2**	**2**	**10**	**10**	**11**	**12**	**11**	**14**	**13**

APPENDIX D

This appendix contains all publications relevant to the operations, research, and reclamation of Castle Mountain Mine in addition to those listed in Section 12.0. If the report is summarized in this document, the appropriate Section is referenced.

D.A. Bainbridge and M.W. Fidelibus. 1994. Treeshelters improve woody transplant survival on arid lands (California), *Restoration and Management Notes* 12(1).

D. Bainbridge, R. Franson, C.A. Williams, L. Lippitt, R. MacAller, and M. Fidelibus. 1995. A Beginner's Guide to Desert Restoration. USDI, National Park Service, Denver Service Center.

Fidelibus, M.W. 1994. Jellyrolls reduce outplanting costs in arid land restoration (California), *Restoration and Management Notes* 12(1).

Fidelibus, M.W. and D.A. Bainbridge. Summer 1994. The effect of containerless transport on desert shrubs. *Tree Planters' Notes* 45(3):82-5. See Section 9.15 for summary.

Fidelibus, M., R. Franson, and D. Bainbridge. 1996. Pp. 182-4 *in* Barrow, J.R. et al. (eds.), *Proceedings: Shrubland Ecosystem Dynamics in a Changing Environment.* May 23-25, 1996, Las Cruces, NM. See Section 9.17 for summary.

Franson, R. 1993. Health of plants salvaged for revegetation at a Mojave Desert gold mine: Year Two. *In* Roundy, B.A., E.D. McArthur, J.S. Haley, and D.K. Mann, Proceedings: Wildland Shrub and Arid Land Restoration Symposium, 19-21 October 1993, Las Vegas, NV. Gen. Tech Rep. INT-GTR-315, U.S.D.A. Forest Service, Intermountain Research Station, Ogden, UT. See Section 9.4 for summary.

Franson, R. 1994. The management of greenhouse and transplant nurseries to improve revegetation success at a Mojave Desert gold mine. Pp. 100-101 *in* Proceedings of the Mining Environmental Management Conference, October 1994, Reno, NV.

Franson, R. 1995a. Unique revegetation program at Mojave Desert gold mine eases environmental concern (California). *Restoration and Management Notes* 11(2):179-80.

Franson, R. 1995b. A Dichotomous Key for Selecting Plant Material for Restoration Projects. Submitted to *Restoration and Management Notes.*

Gould, P.T. April 1987. Biological Resources Survey, Castle Mountain Project, Castle Mountains, CA.

Lippitt, L., M.W. Fidelibus, and D.A. Bainbridge. June 1994. Native seed collection, processing, and storage for revegetation projects in the western United States. *Restoration Ecology* 2(2):120-131. See Section 9.9 for summary.

Viceroy Gold Corporation. November, 1989. Soil Survey for the Castle Mountain Project (Greystone Development Consultants).