RRR146

REPORT

WILDLIFE EVALUATION FOR CLOSEOUT/CLOSURE OF THE MOLYCORP TAILINGS FACILITY QUESTA, NEW MEXICO

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Molycorp, Inc.

P.O. Box 469
Questa, NM 87556-0469

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Dr. Douglas Reagan, ecologist, URS Corporation

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List of Acronyms

AE	assessment endpoint
BLM	Bureau of Land Management
CANMET	Canada Centre of Mineral and Energy Technology
GAE	general assessment endpoint
LOAEL	lowest observed adverse effect level
mg/kg	milligrams per kilogram
MMD	New Mexico Mining and Minerals Division
NMDGF	New Mexico Department of Game and Fish
NOAEL	no observed adverse effect level
NRCS	Natural Resources Conservation Service
ORNL	Oak Ridge National Laboratories
ppm	parts per million
SCS	Soil Conservation Service
TRC	Technical Review Committee
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service

The Wildlife Evaluation for the Tailings Facility (Wildlife Evaluation) is part of a larger Closeout /Closure Plan development process under both the New Mexico Mining Act and the New Mexico Environment Department's Ground Water Discharge Permitting process. Both regulations require a closeout/closure plan for final reclamation of the facility once operations cease.

1.1 BACKGROUND

On December 30, 1999 the New Mexico Mining and Minerals Division (MMD) approved an extension for approval of the closeout plan for the tailings facility. The extension included tasks yet to be completed. The Wildlife Evaluation for Closure Work Plan (Molycorp 2000) was submitted February 29, 2000. MMD with the Technical Review Committee (TRC) comments, reviewed and commented on the work plan in a letter dated April 17, 2000 (MMD 2000).

The Wildlife Evaluation is intended to address concerns for wildlife protection when the closeout/closure plan is implemented. The New Mexico Mining Act requires that compliance with environmental standards be met upon closure. This Wildlife Evaluation assesses compliance with relevant environmental standards and meets the extended closeout plan schedule requirements. Current site knowledge and expected conditions upon closure form the basis of this Wildlife Evaluation.

1.2 GOALS AND OBJECTIVES

The goal of the closeout plan at the tailings facility is to develop a self-sustaining ecosystem comparable to that of the surrounding region. The purpose of the vegetation cover at the tailings facility is to: 1) stabilize the cover (dust control); 2) meet an appropriate land use (self-sustaining ecosystem); 3) control erosion (water); and 4) serve as a component of the cover design in terms of water use (evapotranspiration). Development of the self-sustaining ecosystem at the tailings facility will require the establishment of four different plant community zones. Planting the distinct community associations adds an additional layer of diversity of the site, while allowing for the successful establishment of various plant types. The criteria for success of development of a self-sustaining ecosystem have been outlined and addressed in other correspondence (Molycorp 1999a) and is still being discussed (New Mexico Energy, Minerals and Natural Resources Department 2000).

Natural ecosystems provide habitat for wildlife. Consequently, restoration at the tailings facility will create suitable physical and biological conditions for ecosystem development. Appropriate areas will be regraded and revegetated with native vegetation. Once the vegetation in these areas becomes established, native wildlife will invade the area, completing the assemblage of functional groups needed to sustain the ecosystem.

The overall objective of this Wildlife Evaluation is to determine whether expected site closeout conditions will be consistent with the goal of establishing a self-sustaining ecosystem. Objectives also include completing the evaluation in a manner that focuses on information pertinent to closure of the tailings facility. The Wildlife Evaluation will achieve these objectives by:

- Collecting and reviewing previous data generated for the tailings facility as related to wildlife (Section 4.1)

- Reviewing published information on molybdenum and the environment (Section 4.1)
- Surveying other molybdenum mines in North America to review relevant information (Section 4.1)
- Evaluating the future potential wildlife resources and their condition (Section 2.0)

1.3 REPORT ORGANIZATION

This Wildlife Evaluation has 7 major sections. Section 1, Introduction, provides background, goals and objectives for this report, and an overview of the structure of the report. Section 2, Ecological Characterization: Ecosystems, describes the ecosystem surrounding the tailings facility, providing a context for post-closure goals. Section 3, Post-Mining Land Use Goals, includes future management goals, values identification, and general assessment endpoints based on ecological relevance. Section 4, Stressors, describes the chemical and physical stressors. The chemical stressors portion of this section includes a review of the published toxicological literature on molybdenum, a review of relevant data previously generated at the tailings facility, and a survey of other molybdenum mines. Section 5, Vegetation Closure Evaluation, provides the conceptual revegetation plan and outlines the revegetation monitoring program. Section 6, Wildlife Closure Evaluation, discusses the effects of closure on wildlife and outlines the wildlife monitoring program. Section 7, Literature Cited, lists references used to develop this report.

The tailings facility is located west of the Village of Questa and one and a half miles east of the Guadalupe Mountains (Figure 1). The Red River canyon is approximately one mile south of the tailings facility. The tailings facility has two large diversion (water) ditches that border the facility on the east and on the west. The elevation of the site is approximately 7,500 ft. and the final elevation of the tailings facility will be approximately 7,600 ft. Annual precipitation averages 12 inches with the historical record (1948-1996) showing a range from a low of 7 inches in 1956 to a high of 22 inches in 1986. The growing season is about 129 days (U.S. Department of Agriculture [USDA] Soil Conservation Service [SCS] 1982). The vegetation in the region includes big sagebrush, western wheatgrass/big sagebrush, and piñon-juniper/big sagebrush associations at lower elevations and Ponderosa pine-Douglas fir associations at the higher elevations (Kennedy and Stahlecker 1986, Elmore 1976).

2.1 VEGETATION

The pre-existing vegetation at the tailings ponds has been determined indirectly based on aerial photos (prior to 1965), talking to long-time residents of Questa and examining the surrounding areas. Two ecosystems dominate: the sagebrush community and the piñon-juniper woodlands (Photos 1-5). The sagebrush ecosystem generally occupies plains and plateaus derived from lava flows, ancient lakebeds and broad basins of alluvium (Garrison, et al. 1977). The length of the frost free period ranges from 80 to 120 days with precipitation ranging from 5 to 12 inches, although some areas with as much as 20 inches of precipitation are found. Sagebrush ecosystems are dominated by sagebrush (*Artemesia spp.*) although other shrubs may make up a part of the community. Sagebrush is also found as the only shrub with the understory made up of wheatgrasses, fescues, bromes, etc. The soil types are generally Aridosols; they may have no pedogenic horizons and are typically low in organic matter.

The piñon-juniper woodland is considered a climax community found in areas characterized by low precipitation, low relative humidity, hot summers with high evaporation rates and clear weather with intense sunlight (Eyre 1980, Elmore 1976). Desert shrub (e.g., sagebrush) communities often flank this community. Generally, the piñon-juniper community occupies rocky or rough terrain, while sagebrush or other species occupy the gentle portions of terrain. Soil types associated with piñon-juniper woodlands include Aridosols with pedogenic horizons and moderate to low organic matter. Species associated with piñon-juniper, particularly in well-developed soils (12 inches) include big sagebrush, western wheatgrass, blue grama, cliffrose, bitterbrush and Indian ricegrass. As the canopy closes, or on soils with low water holding capacity, grass production is reduced, shrubs spread out and the closure of the canopy may eventually eliminate the understory.

A fairly extensive habitat description of the area around the tailings facility was completed by Kennedy and Stahlecker (1986) in a report prepared for the Bureau of Land Management (BLM) as part of an avian study. An additional overview of plant species was conducted in 1994 as part of the site assessment for the New Mexico Mining Act permit (Wagner and Harrington 1994). The description by Kennedy and Stahlecker (1986) is still accurate based upon observations made by Molycorp environmental staff over the last four years. Habitat sites in the Guadalupe Mountain Study Area were delineated using aerial photographs and refined through field studies. The general vegetation types were confirmed in the vegetation survey conducted in 1994 (Wagner and Harrington, 1994). Kennedy and Stahlecker (1986) designated seven habitat sites: sagebrush/grassland, piñon-juniper woodland, agricultural lands, wooded canyon benches, canyon slopes, riparian, and upland forest. Mill tailings were mapped but not considered a habitat site (Plate 1). Because of the location of the tailings facility and the proposed reclamation plan, only the sagebrush/grassland, piñon-juniper woodland, and agricultural lands as described by Kennedy and Stahlecker (1986) will be discussed here.

The sagebrush/grassland habitat site is dominated by big sagebrush (*Artemesia tridentata*), and crested wheatgrass (*Agropyron cristatum*), and blue grama (*Bouteloua gracilis*) were the dominant grasses. A total of 11 species were noted on this habitat site. Table 1 contains a complete list of species found in this habitat type. Shrubs and grasses constituted about 53 percent of the total hits recorded in the transects placed in this habitat type (Plate 1). In the area where these transects were placed there was evidence of active removal of sagebrush which affected the distribution of plants. In most cases, these areas were re-planted with crested wheatgrass. Other grasses for this habitat type included: Indian ricegrass (*Oryzopsis hymenoides*), galleta (*Hilaria jamesii*) and bottlebrush squirreltail (*Elymus elymoides* formerly *Sitanion hystrix*). Bare ground, gravel and litter are predicted to cover about 80 percent of the ground cover in this potential plant community.

This habitat site covered about 6,250 acres within the area evaluated in 1986 and depicted in Plate 1. This habitat is generally on the nearly level to gently sloping mesa lands and rolling hills. The majority of this habitat site occurs between 7,500 and 7,600 ft. although can be found from 7,400 to 8,000 ft.

The piñon-juniper woodland habitat site covered approximately 6,230 acres in the area evaluated by Kennedy and Stahlecker (1986). This community demonstrated much higher diversity with 39 species encountered (Table 1). The canopy coverage was up to 75 percent in some areas. Piñon pine (*Pinus edulis*) accounted for 41 percent of the vegetative hits recorded on the transects in this habitat type. Piñon pine averaged 817 plants/acre with juniper (*Juniperus spp.*) averaging 100 plants/acre. The habitat site is characterized by extensive tree canopy cover with moderate ground cover (24.5 percent average of basal hits). Big sagebrush is the most common shrub in this habitat site with mountain mahogany (*Cercocarpus montanus*) and Ponderosa pine (*Pinus ponderosa*) found in the more mesic sites of this habitat. While ground cover is low, many species of grasses were found with no one species of grass dominant. The common grasses found included blue grama, western wheatgrass (*Pascopyrum smithii* formerly *Agropyron smithii*), bromes (*Bromus spp.*), muttongrass (*Poa fendleriana*), and needlegrass (*Stipa spp.*).

The agricultural land habitat site as described by Kennedy and Stahlecker (1986) was the Molycorp property surrounding the tailings facility. It was comprised of 420 acres mostly north of the tailings facility which is approximately 800 acres. It was presumed that the reclamation experiments begun in 1975 at the tailings facility, as well as the previous agricultural activities in these areas, have influenced the species composition.

The plant community associated with this habitat site consisted of a relatively dense herbaceous layer with scattered shrubs and trees. This plant community has changed somewhat over the last 15 years, in that more big sagebrush and rabbitbrush are present now relative to 1986 based on observations made since 1996 (Tables 2 and 3).

The Natural Resources Conservation Service (NRCS, formerly the SCS) listed the potential vegetation for this habitat site, based upon undisturbed sites (USDA SCS 1981), as follows: piñon pine, Apache plume (*Fallugia paradoxa*), wood's rose (*Rosa woodsii*), Gambel oak

(*Quercus gambellii*), gooseberry (*Ribes spp.*), mountain brome (*Bromus marginatus*), hairy grama (*Bouteloua hirsuta*), muttongrass, and mountain muhly (*Muhlenbergia montana*).

2.2 WILDLIFE

Animals associated with sagebrush ecosystems include mule deer (primarily winter use), gophers, coyotes, jackrabbits and rats. Bird populations are generally low during the breeding season with an average of 25 pairs for 100 acres. Major influent birds include red-tailed hawk, Swainson hawk, owls and eagles (Garrison et al. 1977). Associated with piñon-juniper woodlands, mule deer, coyote, bobcat and elk may be locally important (Garrison et al. 1977, Eyre 1980). Also found are the wood rat, cliff chipmunk, jackrabbit, porcupine and gray fox among others. Some of the birds found in piñon-juniper woodlands include the gray titmouse, Woodhouse's jay, red-tailed hawk, piñon jay and rock wren.

A site-specific wildlife evaluation was completed by ENSR in 1994 as part of the site assessment for the New Mexico Mining Act permit. Additional information is available from the BLM, U.S. Forest Service (USFS), and New Mexico Department of Game and Fish (NMDGF) for the general area and habitats as well as the Kennedy and Stahlecker (1986) report on avian habitat.

Mammals that typically use the tailings facility and surrounding habitat include mule deer, elk, black bear, mountain lion, bobcat, coyote, gray fox, raccoon ringtail and cottontail (ENSR 1994). Black bear and mountain lion are limited in numbers, but have been reported just west of the tailings ponds and bobcat have been sighted at the tailings ponds in the past.

Information is available from the NMDGF regarding large mammal counts in the area; BLM (1998) briefly discussed elk and deer populations in the Rio Grande corridor. Mule deer populations in the area (Hunt Unit 53) have apparently decreased since 1994 while elk populations have increased. The annual aerial survey data on mule deer collected by the NMDGF showed observations of 188, 226 and 194 in 1992, 1993 and 1994 respectively (ENSR 1994). The December 1999/January 2000 count showed observations of very few deer (Catanach 2000). On the other hand, elk counts from 1992 to 1994 showed 96, 116 and 107 elk respectively (ENSR 1994) in the unit while the 1999/2000 count showed 500 to 700 elk (Catanach 2000). It is expected that mule deer use habitats to the west of the tailings facility (ENSR 1994). Elk and deer generally may be found in similar habitats. Elk are primarily grazers feeding on grasses, forbs, and woody vegetation. Mule deer are primarily browsers depending on a wide variety of shrubs.

Numerous small mammals including the white-tailed jackrabbit, Ord's kangaroo rat, deer mouse, pocket gophers and least chipmunk occur on and near the tailings. Amphibians and reptiles found in the area include the western spadefoot toad, leopard frog, collard lizard, great plains skink, bullsnake, and prairie rattlesnake (ENSR 1994).

Kennedy and Stahlecker (1986) recorded 133 avian species in a study conducted in the Guadalupe Mountain Study Area, which encompassed the tailings facility. The survey was completed in August through September 1984 and April through June 1985. For the Sagebrush/Grassland habitat, 22 species of birds were recorded at least once. The majority of breeding pairs were Brewer's sparrow, Vesper sparrow and Sage sparrow. The piñon-juniper woodland habitat site recorded 35 species of birds. The most common species were black-throated gray warblers, plain titmice, mountain chickadees and brown-headed cowbirds. For the agricultural habitat, 24 species of birds were recorded. Western meadowlarks were the most obvious species. Raptors were found throughout the area, including the red-tailed hawk, American kestrel, great-horned owl, and saw-whet owl.

2.3 THREATENED AND ENDANGERED SPECIES

Using information from the BLM (BLM 1998, des Georges 1999) and from the USFS Questa Ranger District (Long 1999), potential habitat for threatened and endangered species was evaluated. The species listed below are the only threatened or endangered species which potentially would occur, based on current information.

American peregrine falcon and Arctic peregrine (migration only). According to the BLM (1998) peregrine falcons are known to migrate seasonally through the area and have historically nested in the area. There is one historical nesting site mentioned in the Upper Rio Grande area that has been monitored since 1990 with no activity recorded at this site. There are potentially other sites, but no record of activity at these sites is available. There do not appear to be any active nesting sites for the peregrine falcon in the vicinity of the tailings ponds. The Arctic subspecies would only migrate through New Mexico.

Bald Eagle: New Mexico does provide habitat for bald eagle wintering and migration. No bald eagle nesting has been identified on BLM administered lands (the most likely location for nesting near the tailings). The only documented winter roosting area along the Rio Grande is south of Pilar, more than 25 miles south of the tailings facility. The summer use habitat could potentially include the Red River (BLM 1998).

Southwestern willow flycatcher: The southwestern willow flycatcher is found along riparian habitats where dense groves of willow, alder and other species are present. For breeding, surface water must be present near the riparian habitat. Upon closure, none of the tailings facility habitat would meet this description. Most of the documented sightings of southwestern willow flycatcher have been south of Taos (BLM 1998).

Table 1

SPECIES FOUND IN THE SAGEBRUSH/GRASSLAND HABITAT AND THE PIÑON-JUNIPER HABITAT

Species (common name)	Species (scientific name)	Sagebrush / grassland [1]	Piñon-Juniper [1]
Sagebrush	*Artemesia tridentata*	5530 stems/acre	1067 stems/acre
Rabbitbrush	*Chrysothamnus nauseosus*	210 stems/acre	na
Broom snakeweed	*Gutierrezia microcephala*	33 stems/acre	na
Piñon pine	*Pinus edulis*	33 stems/acre	817 stems/acre
Juniper (Rocky Mtn.)	*Juniperus scopulorum*	na	83 stems/acre
Juniper (one-seed)	*J. monosperma*	na	17 stems/acre
Ponderosa Pine	*Pinus ponderosa*	na	X
False tarragon	*Artemesia draccunculus*	na	3 percent of total hits
Mountain mahogany	*Cercocarpus montanus*	na	X
Crested wheatgrass	*Agropyron cristatum*	19 percent of totals hits	na
Blue grama	*Bouteloua gracilis*	12 percent of total hits	7 percent of total hits
Bottlebrush squirreltail	*Sitanion hystrix (now Elymus elymoides)*	X	X
Western wheatgrass	*Agropyron smithii (now Pascopyrum smithii)*	X	3 percent of total hits
Wheatgrass	*Agropyron spp.*	na	X
Brome	*Bromus spp.*	na	X
Grass (unidentified)	*Graminae*	na	X
Fendler three-awn	*Aristida fendleriana*	X	na
Needlegrass	*Stipa spp.*	na	X
Sideoats grama	*Bouteloua curtipendula*	na	X
Indian ricegrass	*Oryzopsis hymenoides*	na	X
Muttongrass	*Poa fendleriana*	na	X
Buckwheat	*Eriogonum spp.*	X	na
	Leucelene ericoides	X	na
Plains prickly pear	*Opuntia polycantha*	X	X
	Petradoria pumila	na	X
Redroot wild buckwheat	*Eriogonum racemosum*	na	X
White ragweed	*Hymenopappus spp.*	na	X
Bladderpod	*Lesquerella spp.*	na	X
Rock jasmine	*Androsace septentrionalis*	na	X
Wee Mary buckwheat	*Eriogonum jamesii*	na	X
Pinque	*Hymenoxys richardsonii*	na	X
Datil	*Yucca baccata*	na	X
Aster	*Machaeranthera spp.*	na	X

(Kennedy and Stahlecker 1986)

[1]Information under habitat indicates average number of stems per acre, the average percentage of total hits from the transects in each type, presence (X) or absence (na) of a species in each habitat type.

Table 2

SPECIES FOUND IN THE AGRICULTURAL LANDS HABITAT SITE TRANSECTS FROM THE GUADALUPE MOUNTAIN STUDY AREA

Species – Common Name	Species – Scientific Name
Sleepygrass	*Stipa robusta*
Smooth brome	*Bromus inermis*
Alfalfa	*Medicago sativa*
Crested wheatgrass	*Agropyron cristatum*
Western wheatgrass	*Agropyron smithii (now Pascopyrum smithii)*
Unidentified grass	*Graminae*
Slender wheatgrass	*Agropyron trachycaulum (now Elymus trachycaulus)*
Foxtail barley	*Hordeum jubatum*
Hairy brome	*Bromus ciliatus*
Rush	*Juncus spp.*
American sloughgrass	*Beckmannia syzigachne*
Bluegrass	*Poa spp.*
Bottlebrush squirreltail	*Sitanion hystrix (now Elymus elymoides)*
Summer cypress	*Kochia scoparia*
Sunflower family	*Compositae*
Curlycup bumweed	*Grindelia squarrosa*
Flag	*Iris missouriensis*
Aster	*Machaeranthera spp.*
	Haplopappus spinulosus
Sweetclover	*Medicago officinalis*
Rocky Mountain Juniper	*Juniperus scopulorum*
Rabbitbrush	*Chrysothamnus nauseosus*
Sagebrush	*Artemesia tridentata*

(Kennedy and Stahlecker 1986)

Sleepygrass constituted 15 percent of the total hits on the transects (average) and summer cypress constituted 12 percent of the total hits (average).

Table 3

SPECIES FOUND IN TRANSECTS FROM 1998 AND 2000

Species – Common Name	Species – Scientific Name
Rubber rabbitbrush	*Chrysothamnus nauseosus*
Big sagebrush	*Artemesia tridentata*
Juniper	*Juniperus spp.*
Wheatgrass	*Agropyron spp.*
Arizona fescue (tentative i.d.)	*Festuca arizonica*
Indian ricegrass	*Oryzopsis hymenoides*
Unidentified grass	*Graminae*
Bottlebrush squirreltail	*Elymus elymoides*
Sweetclover	*Melilotus officinalis*
Aster	*Machaeranthera spp.*
Alfalfa	*Medicago sativa*
Cactus	*Opuntia spp.*
Yucca	*Yucca spp.*

2000 transect information from Robertson GeoConsultants 2000a.

Table 4

PLANTING COMPOSITION OF PLANT COMMUNITY TYPES FOR RECLAMATION OF THE TAILINGS FACILITY UPON CLOSURE

Plant Community Type	percent Trees / Typical Species	percent Shrubs / Typical Species	Grasses / Forbs Seeding Rate / Typical Species
Piñon-Juniper Woodland	75 percent trees / 2 spp. minimum, e.g., piñon, juniper, NM locust, etc.	25 percent / 2 spp. minimum, e.g., buffaloberry, NM foresteria, Apache plume, big sagebrush, etc.	15 PLS / ft^2 (drilled rate), e.g., blue grama, western wheatgrass, galleta, aster, buckwheat, etc.
Mixed Woodland and Shrubland	50 percent trees / 2 spp. minimum, e.g., piñon, juniper, NM locust, etc.	50 percent / 2 spp. minimum, e.g., buffaloberry, NM foresteria, Apache plume, big sagebrush, etc.	15 PLS / ft^2 (drilled rate), e.g., blue grama, western wheatgrass, galleta, aster, buckwheat, etc.
Shrub Community	50 percent trees / 2 spp minimum, e.g., piñon, juniper, NM locust, etc.	90 percent / 3 spp. minimum, e.g., buffaloberry, NM foresteria, Apache plume, big sagebrush, etc.	15 PLS / ft^2 (drilled rate), e.g., blue grama, western wheatgrass, galleta, aster, buckwheat, etc.
Grasses and Forbs	None	None	35 PLS / ft^2 (drilled rate), e.g., blue grama, western wheatgrass, galleta, aster, buckwheat, etc.

From: Robertson GeoConsultants 1998. For complete plant list see Robertson GeoConsultants 1998 Table 4-3.

3.1 FUTURE MANAGEMENT GOALS

The post-mining land use is cold desert woodland/shrubland/grassland. All ponded water at the tailings facility will be removed upon closure. Development of a self-sustaining ecosystem comparable to the surrounding region is the regulatory goal of the closeout plan at the tailings facility. Additionally, meeting all applicable environmental standards after closure is also required. Molycorp has proposed a vegetation cover for the site upon closure that has four purposes as follows: (1) to stabilize the cover (dust control); (2) to meet an appropriate post mining land use (self-sustaining ecosystem); (3) for erosion control (water); and (4) as a component of the cover design in terms of water use (evapotranspiration).

3.1.1 Initial Goals

Establishment of conditions leading to a self-sustaining ecosystem at the tailings facility entails the establishment of four different plant community zones. Planting the distinct community associations adds an additional layer of diversity of the site, while allowing for the successful establishment of various plant types. The criteria for success of development of a self-sustaining ecosystem has been outlined and addressed in other correspondence and is still under discussion.

The four different plant community zones (Table 4) have been described in detail in the Questa Tailings Facility Revised Closure Plan (Robertson GeoConsultants 1998). Briefly, the zones are as follows: piñon-juniper woodland, mixed woodland and shrubland and shrub community. There will also be smaller areas of grass–forb communities primarily to enhance erosion control at the site. Each of the communities will fit into the overall management goals as well as being managed to some degree individually.

3.1.2 Long-term Goals

Maintenance of the vegetative cover is important to the long-term success of closure at the site. The objective is to establish plant communities suitable to the region, and allow for the development of a functioning ecosystem at the site which is the long-term goal. The regional landscape suggests that establishing the four plant communities will allow for blending of these into the larger, existing ecosystem. Depending upon the uses that are identified for the woodland community, the area could be managed for firewood production, piñon nut production or other uses. Identification of these uses can be made after successful establishment of vegetation. Prior to establishment, management is the same regardless of end uses (with the design parameters).

3.2 VALUES IDENTIFICATION

Environmental decision-making should be based on values and should focus on valued aspects of the environment. To ensure that this Wildlife Evaluation focuses on relevant ecological concerns, values are identified early in the process. This allows the evaluation to focus on ecologically relevant organisms. Explicit expressions of the environmental values that are to be protected are called assessment endpoints (AEs) (Suter 1989, U.S. Environmental Protection Agency [USEPA] 1992), operationally defined as ecological entities and their attributes (USEPA 1998).

All values placed on ecological resources are ultimately human values (Norton 1987); however, these can be logically subdivided into ecological values and human values. In this context, ecological values refer to characteristics that are necessary to maintaining the ecosystem. Human values refer to direct human uses (e.g., hunting. fishing, or timber extraction) and to non-consumptive considerations (e.g., aesthetic and spiritual values such as wilderness or religious uses by indigenous people).

The USEPA (1998) provides three criteria for identifying values to be protected:

- Ecological relevance
- Relevance to management goals (societal relevance)
- Susceptibility to known or potential stressors.

Ecologically relevant endpoints are those that reflect important ecological characteristics and are functionally related to other endpoints. Ecological values that people care about (i.e., societal values) are likely to be the real drivers in risk management decisions (USEPA 1992, 1998). These two criteria encompass the relevance to all levels of organization within an ecosystem and the human values derived from the ecosystem.

The third criterion, susceptibility to environmental stressors, addresses both sensitivity and exposure. For chemical stressors (i.e., molybdenum), properties such as the ability to biomagnify up food chains or affect certain receptor groups (e.g., mammals, fish, invertebrates) are important considerations in evaluating possible effects on wildlife. Exposure to physical stressors, such as substrate modification during mining, are also relevant to mine closure effects on wildlife.

Identifying values based on ecological and management (societal) relevance and subsequently evaluating susceptibility to environmental stressors (e.g., molybdenum) provides a science-based means of identifying values and evaluating potential effects. Such an approach avoids the "most sensitive species" bias that in some studies has lead to irrelevant or inappropriate conclusions.

Because multiple levels of ecological organization may be adversely affected by environmental stressors, the process of determining ecological values can seem daunting. This is particularly true for study sites that support a variety of natural ecosystems. Identification of ecological values in the evaluation of mine effects on wildlife eliminates the likelihood of missing important values to be considered. This section describes a systematic and comprehensive process for identifying ecological values, particularly wildlife, to be protected for the restored ecosystem potentially affected by environmental stressors following mine closure at the tailings facility.

The process of identifying general values, hereafter referred to as General Assessment Endpoints (GAEs) (i.e., values to be protected), provides a means of documenting the rationale for determining values for each potentially affected ecosystem, irrespective of their potential exposure to environmental stressors. These values encompass ecological and human use values at all levels of ecological organization, thus providing a basis for determining site-specific ecological values. Site-specific ecological values are subsequently identified by considering which of the general values may be susceptible to stressors (i.e., molybdenum). This approach to identifying ecological values as the basis for management decisions is described in detail by Reagan et al. (1999) and Reagan (in press).

Ecologically Relevant Attributes – While feeding relationships are relevant characteristics of each functional component of the terrestrial food web, each component may have additional ecologically relevant attributes that define its overall ecological value. For many functional components, the non-trophic attributes are at least as important as their role in nutrient and energy transfer through the food web.

Relevant attributes of the functional components of the ecosystem are defined below:

- FOOD – Source of energy and nutrients for ecosystem components.
- HABITAT – Shelter or structural support for other organisms.
- ENERGY and NUTRIENT FIXATION – The fundamental process of converting inorganic chemicals to organic compounds that can provide energy and nutrients to other living components of the ecosystem.
- DECOMPOSITION – The breakdown of non-living organic matter, recycling nutrients and preventing an accumulation of non-living organic matter that would interrupt energy and nutrient cycling processes.
- PROPAGULE DISPERSAL – The distribution of seeds and spores from their origin to other locations. The process is important for recolonization and natural revegetation following disturbance.
- POLLINATION – The cross-fertilization by nectar and pollen feeding animals is the sole means of reproduction in many plant species.
- PREDATION – The killing and consumption of other animals by carnivores including top predators, insectivores, and parasites. Predation is a means of exerting control over population dynamics and trophic structure within some ecosystems (Osenberg and Mittelbach 1996).
- CONTROL – Either "top down" or "bottom up" effect on the structure (composition and abundance) or function of the ecosystem.

The various attributes for each of the functional components of the ecosystem are presented in Table 6.

While all organisms are food for other organisms, different functional components provide other services within an ecosystem. Thus, trees not only provide food for herbivores, they also provide structural habitat for arboreal species and create shaded microclimates beneath the canopy. Animals that feed on pollen and nectar play a relatively minor role in nutrient and energy transfer through the ecosystem, but they provide the critical function of pollination for many plant species. Seed-eating birds, such as Clark's nutcracker, not only provide a substantial prey base for predators but frequently carry seeds some distance from the location where they find them, thus playing an important role in seed dispersal and germination.

3.3 GENERAL ASSESSMENT ENDPOINTS BASED ON ECOLOGICAL RELEVANCE

GAEs based on functional groups in the restored natural ecosystem at the tailings facility can be developed directly from Table 6, which provides a comprehensive summary of the attributes of all functional components of the ecosystem. The thorough nature of the process ensures that

Table 5

FUNCTIONAL COMPONENTS OF THE TERRESTRIAL ECOSYSTEM OF THE MOLYCORP TAILINGS FACILITY

Basic Trophic Category	Functional Component
Producer	Herbaceous Plants Woody Shrubs Trees Mycorrhizal Fungi
Consumers	<u>Herbivores</u> Fruit and Seed Eaters Leaf and Twig Eaters Root Eaters Nectar Feeders <u>Carnivores and Omnivores</u> Intermediate and Small Predators Omnivores Top terrestrial Predators Top arboreal Predators Detritivores and Scavengers
Decomposers	Chemical Decomposers

Table 6

ECOLOGICALLY RELEVANT ATTRIBUTES OF THE FUNCTIONAL COMPONENTS IDENTIFIED FOR THE TERRESTRIAL ECOSYSTEM OF THE MOLYCORP TAILINGS FACILITY

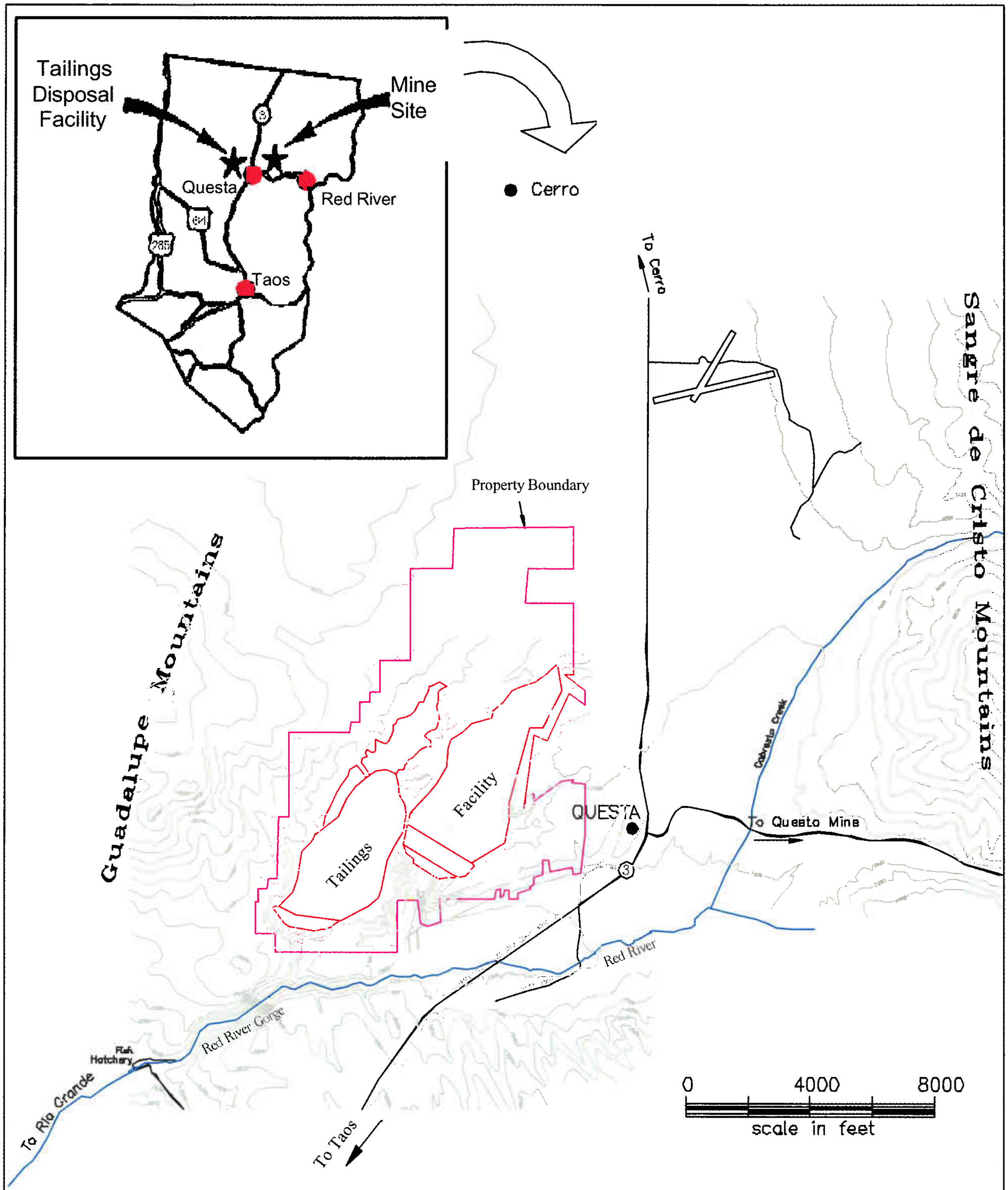
Functional Components	Food	Habitat	Primary Production	Pollination	Seed Disp.	Decomp.	Control
Trees, herbaceous plants, woody shrubs	X	X	X				
Mycorrhizal Fungi			X (enhancer)				X
Fruit and Seed Eaters	X				X		X
Leaf and Twig Eaters	X						
Root Eaters	X						
Nectar Feeders	X			X			
Intermediate and Small Predators	X						
Omnivores	X						
Top Terr. and Arboreal Predators							X
Detritivores and Scavengers						X	
Chemical Decomposers						X	

Table 7

EVALUATION OF MINE CLOSURE EFFECTS ON GENERAL ASSESSMENT ENDPOINTS (VALUES TO BE PROTECTED) AT THE MOLYCORP TAILINGS FACILITY

General Ecological Assessment Endpoint	Predicted Mine Closure Effect
Healthy sustainable ecosystem	Current areas of physical disturbance will be revegetated with native plants typical of surrounding terrestrial ecosystems. Most native animals and plant species are expected to re-invade the area. Some areas may not be suitable for all species (e.g., cap areas not suitable for pocket gophers or prairie dogs); however, these areas are not expected to have a significant adverse effect on the health or sustainability of the terrestrial ecosystem.
Biodiversity	No significant adverse effects are expected on the terrestrial ecosystem. Local reductions in biodiversity are expected in areas of extensive disturbance and reclamation.
Functional integrity	No adverse effects are anticipated.
Nutrient and energy dynamics	No adverse effects are anticipated.
Herbaceous plants	Adverse effects are anticipated as a result of soil disturbance during mine closure activities. These effects are expected to be transient, and all disturbed areas on site will be revegetated.
Woody shrubs	(as above)
Trees	(as above)
Fruit and seed eaters	(as above)
Leaf and twig eaters	(as above)
Root eaters	Pocket gophers may be exposed to elevated concentrations of molybdenum in the tailings. Any adverse effects are expected to be sublethal. The population of pocket gophers inhabiting the regional ecosystem is not likely to be affected significantly. Discontinuous distribution of pocket gophers is typical of regional ecosystems, due to limitations of imposed by differences in habitat types (i.e., woody plants inhibit occurrence of pocket gophers) and soil depths.
Nectar feeders	Adverse effects are anticipated as a result of soil disturbance during mine closure activities. These effects are expected to be transient, and all disturbed areas on site will be revegetated.
Intermediate and small predators	(as above)
Omnivores	(as above)
Top terrestrial predators	(as above)
Top arboreal predators	(as above)

General Ecological Assessment Endpoint	Predicted Mine Closure Effect
Detritivores and scavengers	(as above)
Chemical decomposers	(as above)
Threatened and endangered species	No threatened or endangered species are expected to occur at the site; therefore, no adverse effects are expected.
Game species	The total area of disturbance related to tailings closure is only a fraction of the home range of individuals of game species (e.g., mule deer), and all of the area will be revegetated. Therefore, no significant adverse effects on mine closure are anticipated.
Watershed health	Improved by reclamation activities and the resulting improvement (reduction) in seepage from the tailings facility upon closure.
Visual/aesthetic impact	Improved by regrading and reclamation of the tailings facility upon closure.
Mycorrhizal fungi	Improved by regrading and reclamation of the tailings facility upon closure.



Molycorp

Questa Tailings Facility
New Mexico, USA

Wildlife Evaluation Report

Location Map

July 2000 | Figure 1

Figure 2

ECOLOGICAL VALUES IDENTIFICATION PROCESS

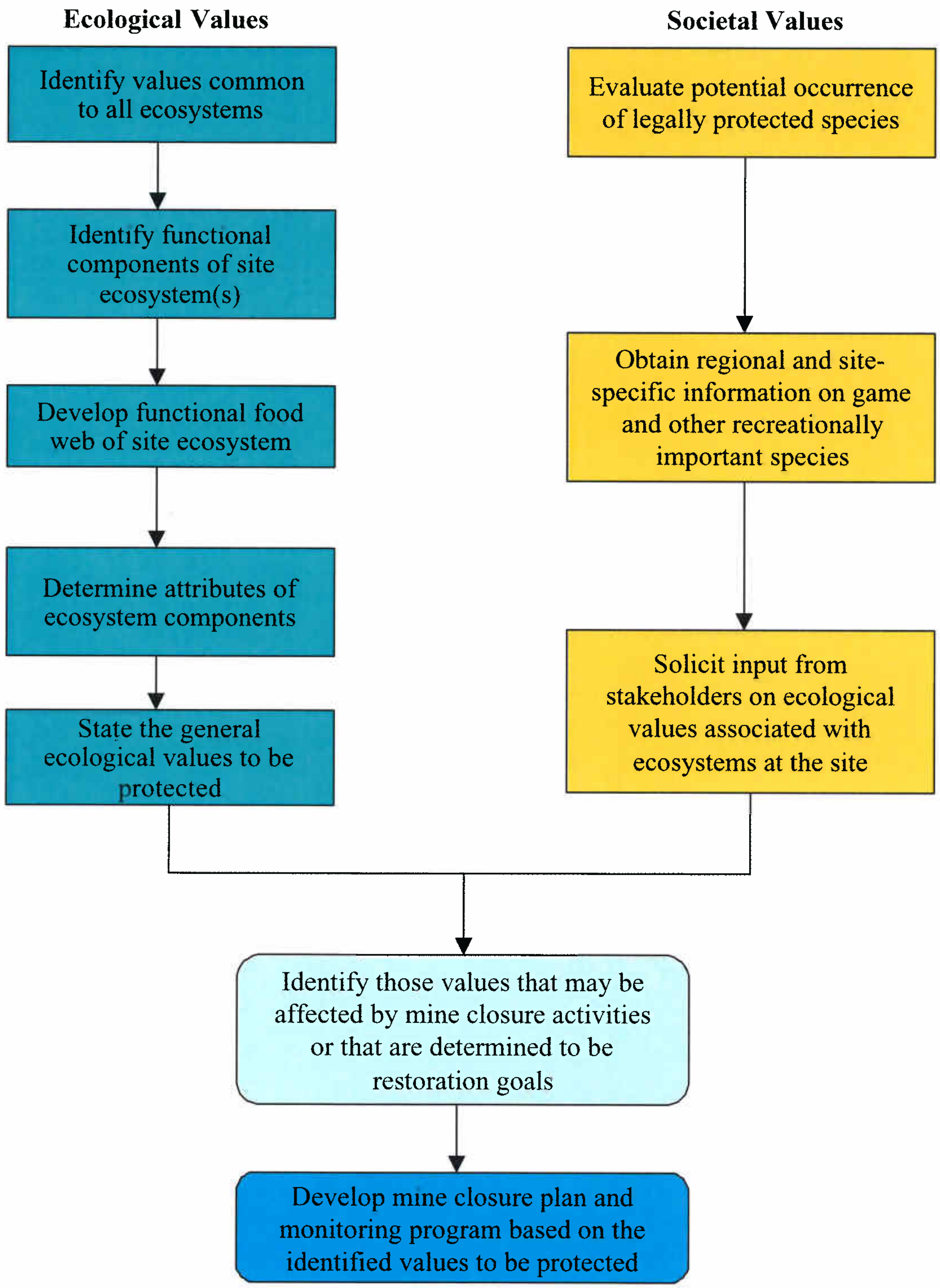
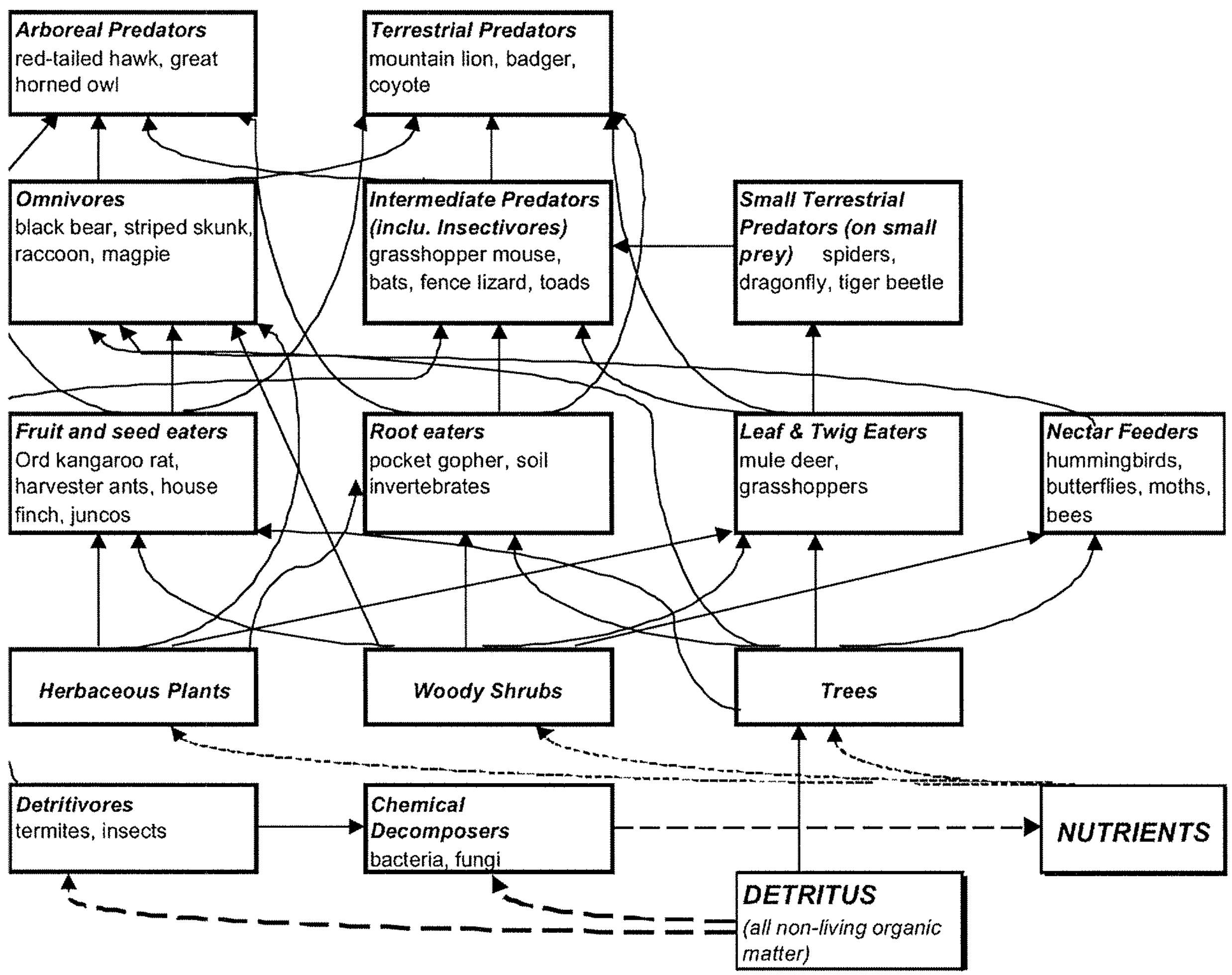


Figure 3

GENERALIZED FUNCTIONAL FOOD WEB FOR THE TERRESTRIAL ECOSYSTEM OF THE MOLYCORP TAILINGS FACILITY



The original landscape of the area that is now the tailings facility has been modified through construction and use of the land for tailings disposal. Physical activities that removed or altered habitat include dam and pond construction and deposition and covering of tailings. Closure of the tailings facility will restore habitat.

Post-mine closure stressors to the terrestrial ecosystem at the tailings facility will be both physical and chemical (i.e., molybdenum).

4.1 CHEMICAL STRESSOR: MOLYBDENUM

Molybdenum at the tailings facility may be present as a result of use of the area for tailings disposal; natural presence in soil; erosion, wind, or water transport of these materials. The tailings and cover soils have been analyzed for nutrient status as well as metals content (Robertson GeoConsultants 2000b). Metals for analysis were selected after consultation with MMD. Results indicate that for metals analyzed iron and aluminum levels were the same as in the cover soils (Table 8). Copper, manganese and zinc levels were in the range of the cover soils or above, but all were less than the "typical" soil levels reported. Molybdenum was only analyzed in the tailings samples and ranged from 0.2 to 1.3 µg/g and is less than for "typical" soils. When this information is combined with information generated by the on-site studies evaluating plant uptake for metals, molybdenum is the only chemical stressor of interest (i.e., no increase in Zn, Cu, Al, Mn, Fe in plants grown on tailings; Dreesen and Henson 1996; USDA SCS 1989).

4.1.1 Molybdenum Toxicity Literature

This section contains a review of the toxicological literature on molybdenum, focusing (for animals) on the ingestion pathway. For ease of comparison, most information is presented in table form. The toxicity summary tables (presented below) summarize the results of dozens of potentially relevant toxicity studies. We obtained the original literature for some studies, and learned about most through secondary sources, which are clearly identified as such in both the tables and the reference section. These secondary sources are generally considered to be authoritative, and include Eisler 1989; USEPA 1979; USEPA 2000; and Canada Centre of Mineral and Energy Technology (CANMET) 1994. In many cases, a single study was covered in several secondary sources, increasing the amount of information that appears in the toxicity summary tables and providing independent confirmation of that information.

Use of secondary sources allowed a more comprehensive coverage of the literature, a clear and important benefit. However, use of secondary sources carries several caveats:

- Some studies may be included more than once on the tables because the secondary sources themselves also used some summary articles, making it impossible to know for sure whether apparently similar studies were indeed one in the same. We believe this is a rare occurrence in the tables; however, when in doubt we have erred on the side of over-inclusiveness.
- The authors of each secondary source had specific purposes as they summarized the original literature. Those purposes may not have been identical to ours. Therefore, much information that is absent from the tables (e.g., No Observed Adverse Effect Levels [NOAELS]) may actually have been provided in the original report, but not have been of interest to the secondary sources.

- Numbers and units in adjacent columns may be slightly different because some secondary sources converted concentrations in food or water to doses.

The toxicity summary tables are provided in Appendix A for terrestrial plants (Table A-1), terrestrial invertebrates (Table A-2), large herbivores (Table A-3), other mammals (Table A-4), and birds (Table A-5).

Molybdenum is an essential nutrient (Underwood 1976, as cited in USEPA 1979; and CANMET 1994). All organisms on the planet have evolved in a heterogeneous environment, characterized by wide variation of concentrations of metals. As a result, wide variation in the concentration of essential nutrients, like molybdenum, is tolerated with no adverse effects through the basic biological process known as homeostasis (Chappell undated; USEPA 1979).

4.1.1.1 Terrestrial Plants

As indicated above, molybdenum is an essential nutrient. Molybdenum is necessary for fixation of nitrogen by bacteria (Gupta and Lipsett 1981, as cited in Eisler 1989). Much of the molybdenum-related literature on plants reports studies of molybdenum insufficiency as opposed to toxicity. For example, brassicas often show specific molybdenum deficiency symptoms. (Fido et al. 1977, as cited in Alloway 1990). Especially for some plants (e.g., lettuce, brussels sprouts, cabbage, cauliflower), the ratio between deficiency and sufficiency is very small; in other plants (e.g., beets, corn) there may be an order of magnitude between deficient and sufficient levels (Gupta and Lipsett 1981, as cited in Eisler 1989).

The key form of molybdenum for plant uptake is molybdate (Tiffin 1972, as cited in Alloway 1990). Molybdenum availability to plants is generally strongly dependant on pH, with greater availability at higher pH. Amendment of soil with lime increases the availability of molybdenum to plants (Kabata-Pendias and Pendias 1984, as cited in Alloway 1990). There is no direct evidence of an active plant uptake mechanism (Tiffin 1972, as cited in Alloway 1990), but phosphorous is known to increase translocation of molybdenum in plants (Fido 1977, as cited in Alloway 1990).

Table A-1 summarizes the literature found on toxicity of molybdenum to plants. Molybdenum toxicity to field crops has never been observed (Soon and Bates 1985, as cited in Eisler 1989). Nor has toxicity to other plants been observed in the field; only under extreme experimental conditions has molybdenum toxicity to plants been observed (Neuman et al. 1987).

4.1.1.2 Terrestrial Invertebrates

Molybdenum has the potential for use in insect control (Eisler 1989). Little information was found regarding molybdenum toxicity in terrestrial invertebrates; it is summarized in Table A-2. High concentrations of molybdenum in food are required to kill invertebrates.

4.1.1.3 Terrestrial Vertebrates

Average absorption of ingested molybdenum is in the range of 20 to 30 percent (McDowell 1992). There is little storage of molybdenum in the tissues, with low levels in most tissues and fluids, and most storage in liver and bone (McDowell 1992). Molybdenum is rapidly eliminated, most commonly through the urine, but also through bile and milk (McDowell 1992).

Molybdenum is a necessary component of several enzymes involved in (1) metabolism of purines, pyrimidines, pteridines and aldehydes; (2) oxidation of sulfite (McDowell 1992; Eisler 1989; CANMET 1994); and (3) the electron transport chain, involving cytochrome C.

Molybdenum in rats has shown evidence of anticarcinogenicity (Eisler 1989). It also protects against or can be used to treat copper liver toxicity and acute inorganic mercury toxicity (Eisler 1989).

As an essential nutrient in animals, molybdenum seems to be of greatest importance in early fetal development; it also is a necessary component of some enzymes (CANMET 1994; and Underwood 1971, Earl and Vish 1979, and Mills and Bremmer 1980; all three as cited in Eisler 1989). Specific requirement levels are not known for many species, but the requirement for chicks and rats appears to be less than 0.02 milligrams per kilogram (mg/kg) diet; for sheep about 0.01 mg/kg diet (CANMET 1994). Three to 5 mg/kg in forage has been suggested as healthy for cattle; less than 0.5 mg/kg for sheep (Eisler 1989 and Garmo et al. 1986, both as cited in CANMET 1994). Birds may require up to 6 mg/kg in their diet for optimal growth (Kienholz 1977, as cited in Eisler 1989).

Among animals, there is unusual variation from species to species (and possibly even strain to strain) in terms of toxic dose of molybdenum and effects manifested (Friberg et al. 1975, as cited in USEPA 1979). Sensitive species (sheep and cattle) excrete molybdenum in the feces, whereas other mammals excrete molybdenum in the urine (Underwood 1971, as cited in Eisler 1989). Cattle are highly susceptible to molybdenum toxicity, followed by sheep, rats, guinea pigs, rabbits, horses, and pigs (USEPA 1979). For example, clinical effects can be seen in cattle grazing on forage with 10 to 20 parts per million (ppm) molybdenum, as compared to rats, in which clinical symptoms are not seen until molybdenum levels in feed reach 100 to 400 ppm (USEPA 1979). Subclinical effects have been observed in rodents eating diets with about 5 to 10 ppm molybdenum (USEPA 1979).

Birds are considered relatively resistant to molybdenum toxicity; adverse effects in birds (on growth) have been observed at 200 to 300 mg/kg in the diet (Eisler 1989). Molybdenum mine tailings at 20 percent of the diet of chicks resulted in no adverse effects (Kienholz 1977, as cited in Eisler 1989).

Normal plants often contain in the range of 1 to 2 ppm molybdenum (USEPA 1979), or 3 to 5 mg/kg (Friberg and Lener 1986, as cited in Eisler 1989); molybdenum is found in all animal tissues, in the range of 0.14 mg/kg to 4.4 mg/kg (Mills and Davis 1987, as cited in CANMET 1994). Some forms of plant molybdenum (e.g., in soy protein) may not be available to monogastric species (CANMET 1994).

Molybdenosis is the widely known clinical disorder resulting in livestock ingesting excess molybdenum. Also known as teart or Peat, it is characterized by diarrhea (scouring), discoloration of hair, loss of appetite, joint abnormalities, osteoporosis, reproductive effects, and occasionally death (Underwood 1976, as cited in USEPA 1979). The critical copper:molybdenum ratio to prevent molybdenosis appears to be in the range of 2:1 to 4:1 (Miltimore and Mason 1971, as cited in USEPA 1979; Alloway 1973, as cited in USEPA 1979).

Another clinical disorder in livestock caused by excess molybdenum is "swayback" in sheep, which is an ataxia in neonatal lambs characterized by demyelinization in the cerebellum or spinal cord (Jensen et al. 1958, Gallagher et al. 1956, and Fell et al. 1965; all as cited in USEPA 1979).

A similar disorder is caused by copper deficiency in rats (DiPaolo and Newberne 1974, as cited in USEPA 1979).

Other ruminants, such as deer, are far less sensitive to molybdenum toxicity (Ward and Nagy 1976, as cited in USEPA 1979). Mule deer are at least an order of magnitude more tolerant of dietary molybdenum than are domestic ruminants, with sensitivity to toxic effects similar to that of swine, horses, and rabbits (Nagy et al. 1975, Ward and Nagy 1976, Ward 1978, and Chappell et al. 1979; all as cited in Eisler 1979). Adverse effects have not been noted in ruminant wildlife until the concentration of molybdenum in the diet reached over 2,500 mg/kg (Eisler 1989).

Excess molybdenum is known in several species to cause copper deficiency, which is often reversed by copper supplementation; sulfate also interacts with molybdenum and copper (Underwood 1976, as cited in USEPA 1979). The literature on molybdenum:copper:sulfate ratios is rich and complex and is included in the toxicity summary tables only where it specifically points to molybdenum toxicity (or lack thereof) in the presence of ample copper. One explanation for the sensitivity of some ruminants to molybdenum is the formation in the rumen of thiomolybdates, which tightly bind copper (or cause binding to other rumen contents), thus impairing copper absorption (Eisler 1989; CANMET 1994).

Table A-3 provides toxicity summary information for large herbivores (most notably ruminants); Table A-4 provides toxicity summary for other mammals; Table A-5 provides a summary of toxicity studies in birds. No toxicity literature was located regarding amphibians or reptiles.

4.1.1.4 Molybdenum Bioaccumulation/Biomagnification

Bioaccumulation is said to occur when a chemical is sequestered by an organism from media (e.g., soil or food) faster than it is eliminated. Thus, it is possible for the concentration in the organism to exceed the concentration in the media. Biomagnification is said to occur when tissue concentrations increase through the trophic levels. Although there is some potential for molybdenum to bioaccumulate, it is not known (or expected) to biomagnify (CANMET 1994; Eisler 1989).

4.1.1.5 Molybdenum Benchmarks

Benchmark values from Eisler (1989) and Oak Ridge National Laboratories (ORNL) are summarized in Table 9. This table should be interpreted with caution, and values must be considered in the broader context of other available information. For example, ORNL benchmarks are modeled across species, requiring (conservative) assumptions about factors like ingestion rate, interspecies variation in sensitivity, bioavailability, matrix effect and home range (other sources of food). When available, actual toxicity studies on the species of interest provides more direct evidence.

4.1.2 Evidence at the Questa Tailings Facility

Two plant uptake studies have been performed by USDA NRCS (formerly USDA SCS) specialists specific to the tailings at the Questa tailings facility. The first study, conducted in 1989, examined above ground concentrations of 10 metals on plants growing on the tailings facility and plants growing off the tailings facility (USDA SCS 1989). The metals examined included: aluminum, arsenic, cadmium, chromium, copper, molybdenum, nickel, lead, selenium, and zinc and were examined in 14 plant species. From the data collected, there was no increase in plant concentrations between no-tailings and tailings sites for aluminum, arsenic, cadmium, lead, nickel, selenium and zinc. Chromium levels slightly increased in plants grown in topsoil over tailings compared to no-tailings sites (8.8 ppm to 10.2 ppm), however, both these levels were well below the tolerable levels reported for cattle (1000 ppm). Indeed, cattle and sheep can tolerate 3,000 ppm chromium in feed for at least several weeks with no adverse effects, and chromic oxide has been used as a fecal marker in these species (McDowell 1992).

Plants grown on tailings, compared with plants not on tailings showed some increase in the levels of copper and molybdenum. Copper levels in plants on no tailings ranged from 4 to 12 ppm with an average of 7.8 ppm, levels on tailings (with and without topsoil) ranged from 4 to 23 ppm with an average of 10.6 ppm.

Molybdenum levels in plants grown on no tailings ranged from 10 ppm to 144 ppm with an average of 27 ppm (most species were in the 10 ppm range with one species recording 144 ppm). For plants grown in tailings (with and without topsoil) the molybdenum levels ranged from 10 ppm to 287 ppm with an average of 79 ppm. All were below the reported tolerable level for mule deer (1000 ppm, Eisler 1989).

The second study, completed in 1993, was a greenhouse study evaluating molybdenum, copper, calcium, sulfur, magnesium, phosphorous, aluminum, manganese, iron, zinc and boron levels in plants grown in cover soil from the tailings facility borrow area and plants grown in 14 cm (5.5 in) of cover soil over tailings (Dreesen and Henson 1996; Fido et al. 1977, as cited in Alloway 1990). Thirty three species of plants were used including legumes, grasses, forbs and half-shrubs and shrubs. It should be noted that these plants were greenhouse grown and fertilized with a slow-release fertilizer containing phosphorous. Some studies have shown that high levels of moisture and phosphorous may increase molybdenum uptake in plants (Davies 1956). Also, the currently proposed cover placement requires 9 or 18 inches of alluvium over the tailings, which would further reduce exposure of plant roots to molybdenum in the tailings (i.e., most range plant roots occur in the upper 8 inches of soil). Across all plant types and species, there were no significant differences in uptake of metals, except for molybdenum. Molybdenum levels increased from 2.9 ppm to 37.4 ppm when grown with tailings below the cover soil. Again, this is well below levels identified as safe for mule deer.

These two studies evaluating metals uptake by plants grown on the tailings found no indication of toxicity effects of molybdenum or other metals on the plants. Evidence of toxicity could include symptoms such as chlorotic leaves, lack of growth or stunting, etc. This is also supported by the subsequent soil analysis performed that indicate levels of metals are in the "typical" or less range (Table 8). Further evidence is provided by the actual field conditions at the site which show no signs of plant toxicity effects of the tailings.

4.1.3 Other Molybdenum Tailings Facilities

A great deal of work has been done at other molybdenum sites in the U.S., in particular at high altitude sites in Colorado. The Urad mine tailings ponds in Colorado were reclaimed from 1974 to 1979 (Trlica and Brown 1992) using waste rock from a molybdenum mine, which was mixed with sewage and wood chips. The waste rock was expected to be high in molybdenum and other metals since some of the rock came from the orebody itself. Under the slightly basic conditions of the plant growth medium covering the Urad tailings, the prediction was that molybdenum uptake by plants might be considerable and of concern. Molybdenum in the growth medium ranged from 0.1 to 10 ppm with a mean of 1.6 ppm. For vegetation samples taken in 1979 from seedings occurring in 1975, 1976 and 1977, molybdenum increased from 104 ppm to 258 ppm for plants that were seeded in 1977. Smooth bromegrass had an average of 42 ppm with white clover having 303 ppm molybdenum. For samples taken in 1985, molybdenum ranged from 182 ppm to 235 ppm across the years of seeding. Smooth bromegrass had an average of 30 ppm and white clover had an average of 397 ppm molybdenum. The conclusion of the study indicated that the only hazard would be to cattle if grazing was restricted only to the reclaimed tailing area.

The Henderson mine and mill conducted reclamation studies in the 1980s looking at cover depth and metal uptake (Trlica et al. 1994). Molybdenum uptake by smooth bromegrass did not change through time. No metals were concentrated in plants to such a level as to be toxic to plants or a hazard to large animals grazing the site. Soil depth of 12 or 18 inches over tailings resulted in better plant growth than 6 inches of soil. After 11 years of growth, the study concluded that 12 inches of soil over tailing is sufficient to maintain a sustainable herbaceous plant community. Soil pH after adding lime increased from 4.9 to 5.9. The 6 inch soil cover depth appeared to reduce the amount of soluble salts migrating upward from the tailings into the soil compared to the 12 and 18 inch depths. The natural precipitation most likely caused sufficient leaching to result in little net movement of salts from the tailings into the soils.

The Climax mine near Leadville, Colorado, is reclaiming tailings using a waste rock cover with organic and inorganic amendments. Both the tailings and the waste rock are acid generating so lime is used to treat the waste rock cover (Brown and Trlica 1996). Recent information indicates that to date no problems have been found with molybdenum uptake on the tailings, however the reclamation program is still in very early stages (Romig, pers. comm. 2000).

4.1.4 Interpretation of Chemical Stressors

Molybdenum concentrations in Questa tailings range from 0.2 to 1.3 μg/g (Table 8); molybdenum in the post-closure cover soil is expected to be in this range or less. These concentrations are lower than the plant benchmarks provided by Eisler (1989) (3 ppm for optimal growth) and Efroymson et al. (1997a) (2 ppm – lowest observed effect concentration). Site concentrations are lower than the benchmark of 200 mg/kg for soil microorganisms and microbial processes (Efroymson et al. 1997b).

The broader perspective of real-life experience at molybdenum mines in general, and the Questa mine in particular, provides a crucial context for interpretation of the potential impacts of molybdenum in soil on development of a self-sustaining ecosystem. As discussed above, studies conducted at other molybdenum mines provide no evidence that mine-related molybdenum interferes substantively with the success of (post-closure) reclamation.

The Questa tailings facility is itself a large demonstration plot for revegetation, demonstrating successful growth of a variety of plants in covered tailings. As discussed previously, there has been no evidence after 30 years of vegetation establishment on various parts of the tailings facility of plant toxicity from the tailings, grown with or without cover over the tailings. Further, the toxicology literature clearly indicates that molybdenum deficiency is common, and that toxicity has never been observed in the field.

Plants grown on tailings or covered tailings have molybdenum concentrations averaging 79 ppm (USDA SCS 1989); Dreesen and Henson (1996) found a maximum molybdenum concentration of 37.4 ppm in plants grown on cover over tailings. These levels are at the low end of the range of LOAEL-based benchmarks for birds, and below the high end of the NOAEL-based benchmark for birds.

Molybdenum concentrations in plants grown on Questa tailings are in the no effects range for mule deer (less than 1,000 mg/kg diet), based on actual experience. These experience-based values are more useful for comparison than the benchmarks provided by Sample et al. (1996), which were extrapolated from toxicity to mice. Extrapolation across species entails uncertainties about ingestion rates, absorption rates, and species-to-species toxicity, which can be avoided when actual data (like the mule deer data in Table A-3) are available. These studies show that (a) 1,000 mg/kg diet is a no effect level for mule deer and (b) whitetail deer had no adverse effects from eating forage grown near a uranium mine with high molybdenum.

For small mammals, molybdenum concentrations in plants grown on Questa tailings exceed benchmark and are generally in the range of the LOAELs found in laboratory studies of rats, but substantially below the LOAELs found in laboratory studies of guinea pigs and rabbits.

4.2 PHYSICAL STRESSORS

Upon cessation of mining activity, closure activities will create physical stressors to the habitat. The specific requirements of closure (i.e., cover thickness) will determine the magnitude and duration of the physical stressors.

At closure, regrading, cover placement and peripheral activities such as modifying the west diversion decant structure will occur prior to revegetation of the site. If the currently covered and vegetated areas are deemed satisfactory for closure, those areas will not be subject to physical stressors. However, any areas that need covering, the borrow areas that provide cover material will be a source.

Stressors will include dirt movement by scrapers or other equipment, removal of borrow material for cover, placement of the cover and seeding and transplanting activities. Once the site is graded and cover is placed, revegetation will occur. After the successful establishment of vegetation (habitat restoration) it is expected that the physical stressors will be minimal. Therefore, the physical stressors will be transient and upon completion of the reclamation, will no longer be evident.

Table 8

SUMMARY FOR METALS ANALYSIS FOR COVER AND TAILINGS

Type	Sample	Aluminum (µg/g)	Copper (µg/g)	Iron (µg/g)	Manganese (µg/g)	Zinc (µg/g)	Molybdenum (µg/g)
Cover Material	Q-2	<0.1	0.2	3.2	2.2	0.2	
	TP-1 (24-32")	<0.1	0.4	1.2	0.5	<0.1	
	TP-2 (2-6")	<0.1	0.6	2.8	0.8	0.1	
	TP-3 (0-12")	<0.1	0.9	5.4	1.5	0.2	
	TP-4 (2-6')	<0.1	0.5	1.8	0.9	0.1	
	TP-5 (0-12")	<0.1	1.3	4.1	1.6	0.1	
Tailings	GS-1	<0.1	2.2	4	6.7	1.5	1.3
	GS-2	<0.1	1.1	3.5	3.8	1	1.3
	GS-3	<0.1	0.4	2.6	1.3	0.3	0.2
"Typical" Soil		None given	15-40 ppm	>200 ppm	500 to 1000 ppm	50 to 100 ppm	<1-24 ppm, avg. 1-2 ppm

From: Robertson GeoConsultants 2000c.

"Typical" ranges are derived from: Donahue et al. 1983. The typical ranges are based on agricultural soils.

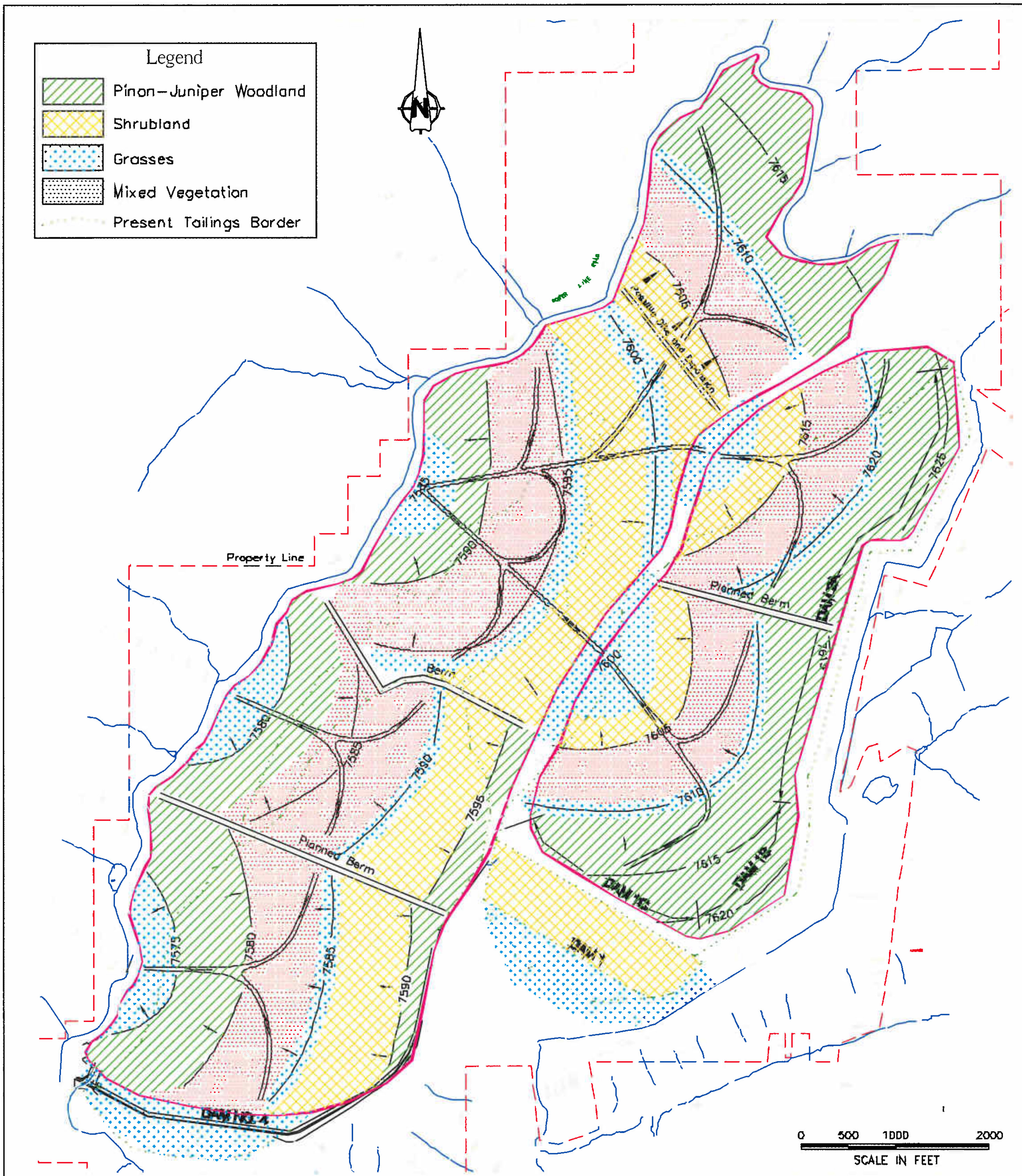
Table 9

ECOLOGICAL BENCHMARKS FOR MOLYBDENUM
(to be interpreted in the context of other evidence)

For Protection of	Interpretation	Concentration	Units	Medium	Source
Plants	lowest observed effect concentration	2*	mg/kg	Soil	Efroymson et al. 1997a
Terrestrial Invertebrates					
Termites	toxic level	1,000	mg/kg	Bait	Eisler 1989
Other Insects	toxic level	5,000	mg/kg	Bait	Eisler 1989
Terrestrial and Wildlife					
Birds	optimal growth	6+	mg/kg	Diet	Eisler 1989
	growth reduction	200 to 300	mg/kg	Diet	Eisler 1989
	NOAEL-based benchmark	3 to 117 +,1	mg/kg	Food	Sample et al. 1996
	LOAEL-based benchmark	30 to 1,180 [1]	mg/kg	Food	Sample et al. 1996
Cattle	maximum tolerable level	6 +	mg/kg	forage	Eisler 1989
Sheep	recommended level	0.5 +	mg/kg dry weight	Forage	Eisler 1989
Mule Deer	no effect level	200 – 1,000 +	mg/kg	Diet	Eisler 1989
	reduced food intake	2,500	mg/kg	Diet	Eisler 1989
Whitetail Deer	NOAEL-based benchmark	1.3 +,2	mg/kg	Food	Sample et al. 1996
	LOAEL-based benchmark	13 [2]	mg/kg	Food	Sample et al. 1996
Small Mammals	NOAEL-based benchmark	0.5 to 2 +,3	mg/kg	Food	Sample et al. 1996
	LOAEL-based benchmark	5 to 20 [3]	mg/kg	Food	Sample et al. 1996
Soil microorganisms and microbial processes	protective	200	mg/kg	Soil	Efroymson et al. 1997b

mg/kg milligrams per kilogram
NOAEL no observed adverse effect level
LOAEL lowest observed adverse effect level

* note that this "effect" level is lower than the molybdenum concentration required by some plants for optimal growth.
\+ nutritional (or otherwise not adverse) effect levels
[1] Lowest value in range is for American robin; highest value is for wild turkey. Based on toxicity to chicken.
[2] ORNL benchmarks for whitetail deer are based on toxicity to mouse.
[3] Lowest value in range is for short-tailed shrew and cottontail rabbit; highest value is for meadow vole. Based on toxicity to mouse.



Molycorp

PROJECT No:

LOCATION: QUESTA TAILINGS FACILITY
NEW MEXICO, USA

Title		
Tailings Conceptual Revegetation Plan		
DATE: July 2000	DRAWN BY: JG	FIGURE: 4

5.1 CONCEPTUAL REVEGETATION PLAN

The revegetation plan has been described in detail in the Revised Closure Plan (Robertson GeoConsultants 1998) and is summarized here. The revegetation plan is designed to achieve a self-sustaining ecosystem compatible with the surrounding area (Photos 1-5, Plate 2). In order to achieve that goal, it is important to consider the dominant plant type desired, the species necessary to ensure a successful reclamation project and the requirements of not only establishing plants but of long term growth and survival. All of these factors have been carefully evaluated in designing the revegetation plan for the site. In addition, research conducted by USDA SCS (1980-1986) provides important information and data for planning (Wolfe and Oaks 1986). Lastly, because of past operational practices, many areas of the tailings facility have been covered with topsoil and seeded successfully over the years. The vegetation is well established at the site and the site can be considered a large test plot that continues to provide evidence of a successful revegetation program (Photos 6-7).

The revegetation plan has three main components: the conceptual design, the planting methods and techniques and establishment period maintenance requirements. Planting methods and techniques will not be discussed here and monitoring and maintenance will be discussed in Section 5.2. The conceptual design encompasses the plant community types to be established, the species that may be planted in each type and the locations of each plant community type (in concept). Details will be subject to the actual elevations and contours at closure. As mentioned previously, the planting of distinct community associations adds an additional layer of diversity to the site while allowing for the successful establishment of various plant types (Figure 4). The communities are described in general broad types: trees, shrubs, and grasses/forbs. Information on the planting composition and seed mixes can be found in Table 4.

The piñon-juniper woodland will consist of all plant types with the major component being trees (i.e., piñon and juniper). Minor components will include shrubs, grasses and forbs. The second community type is the mixed woodland and shrub community, which is a transition zone between the woodland and shrub community types. Nearly equal percentages of trees and shrubs will be planted, with grasses and forbs seeded to make up a minor component of this community. The third community type is the shrub community comprised mainly of shrubs, although again all plant types will be planted including trees at a lower rate (i.e., 10 percent of the total planting). The last type, which covers the smallest area, is the grass and forb community, which will entail planting only grasses and forbs to create buffer strips. These areas are intended to add diversity, provide somewhat quicker cover, and eliminate the slight possibility of surface erosion during the establishment phase of the project.

5.2 REVEGETATION MONITORING PROGRAM

The revegetation monitoring program has been outlined in the Revised Closure Plan (Robertson GeoConsultants 1998) and is summarized here. The formal monitoring program for the vegetation begins four years post-planting. Years one through three post-planting are part of the post-planting establishment and maintenance period (and will include monitoring of establishment) when activities such as weed control, fertilization and supplemental plantings will occur. During the formal monitoring period, years four to sixteen, maintenance will only occur if a problem is considered to be a major threat to the vegetation establishment. Because of bond release requirements under the New Mexico Mining Act, the bonding period is for a minimum of 12 years after the last augmented seeding, fertilization and/or irrigation. The only management/maintenance practice allowed is interseeding to establish diversity and is allowed only in years one to nine of the 12 year period.

The objective of the monitoring is to evaluate plant establishment and growth to ensure and document that the plant community is developing so that it leads to a self-sustaining ecosystem. The annual formal monitoring will include plant counts (density), shrub and tree survival (or stocking) and growth (productivity) and species present (diversity). This monitoring will occur during the growing season, at a time determined to give an accurate representation of the status of the plant communities and will most likely be in late summer or early fall. Other informal monitoring that will occur at least once a year during this period will include cover estimates and production of grasses and forbs. On a biennial basis, formal monitoring will also include determination of cover, grass and forb production. During the last two years prior to potential bond release, all monitoring data will be collected formally.

The monitoring data will be evaluated to determine the status of the revegetation project. As mentioned above, if problems and trends are detected, appropriate action will be taken to ensure the successful establishment of a self-sustaining ecosystem. Data collected during the last two years will be used to document the achievement of reclamation standards.

6.1 CLOSURE EFFECTS (INCLUDING BENEFITS)

6.1.1 Short-Term Effects

In the short-term, closure of the tailings facility will disrupt the plants and animals that live there. These plants and animals are opportunistically living on an active and permitted tailings disposal facility and do not comprise a natural functional ecosystem. The physical stress of covering the tailings with soil and seeding it will have a short-term and localized adverse effect. However, evidence at the tailings facility demonstrates resilience, in that normal operations involve routine covering of tailings and shifting of disposal locations throughout the facility, and plants, both those intentionally seeded and others, re-establish themselves effectively, followed by animals. The overall long-term ecological benefits of closure outweigh the short-term disruption.

6.1.2 Long-Term Effects

The long-term effect of closure will be re-establishment of a healthy, natural, self-sustaining ecosystem at the tailings facility. This ecosystem will include 4 plant community types, re-creating natural transition zones consistent with naturally occurring patterns. Studies on Questa tailings demonstrate that target revegetation species will grow successfully on tailings or tailings with 8 inches of cover or more (Wolfe and Oaks 1986; Robertson GeoConsultants 2000b).

As the plant-based habitat becomes established, animals will move in from surrounding similar habitat, incorporating the new habitat into their home range (for animals with large home ranges) or living their entire lifetimes on the former tailings facility. Game species and threatened and endangered species are expected to thrive in the new habitat on the tailings. For large herbivores, molybdenum concentrations in food plants will be well within safe levels. Molybdenum levels will be lower in animal tissues than in plants and there is no evidence of increased sensitivity to molybdenum toxicity, so large omnivores and carnivores will not experience toxicity. Also, animals with large home ranges will utilize the former tailings facility only intermittently, thus further reducing exposure to molybdenum.

Terrestrial invertebrates and soil microorganisms will not be affected by molybdenum in the area, and are expected to re-establish themselves naturally as the habitat becomes established.

Smaller animals and those with smaller home ranges will also move into the habitat from surrounding areas. It is possible (but not likely), that molybdenum levels in plants will affect growth or reproduction of some species that (1) rely on plants for most of their diet and (2) are very sensitive to molybdenum. This is not expected to have an overall negative impact on the ecosystem as a whole because (1) other species that are less sensitive to molybdenum will opportunistically fill the niche, (2) the expanse of potentially impacted area is small relative to the much larger overall established regional ecosystem, and (3) sufficient replacement prey-base will be available in the surrounding habitat or made up of less sensitive species. The potentially impacted species thrive elsewhere in the surrounding regional ecosystem and their overall survival and success is not jeopardized by improvement of the habitat at the tailings facility.

6.2 WILDLIFE MONITORING PROGRAM

Wildlife monitoring will be conducted in conjunction with the vegetation monitoring program. It is currently anticipated that as a minimum, beginning year 10 after closure, pellet counts will be conducted annually for 2 years at the tailings facility and compared with pellet counts in the surrounding ecosystem. This will be conducted in a scientifically sound manner. A final determination as to the specific type of monitoring will be made as the physical (vegetation) structure of the ecosystem becomes manifest and the wildlife trophic levels become established.

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Table A-1

SUMMARY OF TOXICITY STUDIES OF MOLYBDENUM: TERRESTRIAL PLANTS

Strain	Year of Publication	Form of Molybdenum	Route of Administration	Concentration in Soil	NOAEL	LOAEL	Adverse Effects	Citation
Okra (*Abelmoschus esculentus*)	1983	Sodium molybdate	In soil	1 mg/kg 2 mg/kg 3 mg/kg	3 mg/kg		Increased growth and yields at all levels	Singh and Mourya, aci Eisler 1989
Cashew (*Anacardium occidentale*)	1986		In soil	Low Mo and excess Mn and low pH		Deficiency	Yellow leaf spots: defoliation	Subbaiah et al. 1986, aci Eisler 1989
Florida citrus	1986					Deficiency		Subbaiah et al. 1986, aci Eisler 1989
Corn and bromegrass (*Bromus inermis*)	1985	Mo in sludge	In soil	4.8 to 6 mg/kg			Tissue concentrations after several years of application: bromegrass: 1.9 mg/kg dry weight corn: 3.7 mg/kg dry weight lime-treated sludge increased Mo concentrations in plant tissue	Soon and Bates, aci Eisler 1989

aci as cited in
bw body weight
d day
kg kilogram
L liter
LOAEL lowest observed adverse effect level
µg micrograms
mg milligrams
NOAEL no observed adverse effect level
ppm parts per million
USEPA U.S. Environmental Protection Agency

NOTE: mg/kg designates a concentration in feed, soil, or other medium: mg/kgbw designates a dose.

Table A-2

SUMMARY OF TOXICITY STUDIES OF MOLYBDENUM: TERRESTRIAL INVERTEBRATES

Strain	Year of Publication	Form of Molybdenum	Route of Administration	Dose or Concentration In Food	NOAEL	LOAEL	Adverse Effects	Citation
Termite (*Reticulitermes flavipes*)	1987		In bait	1,000 mg/kg			Mortality in termites, beginning after day 16 and reaching 99% by day 48: only change days 8-10 was color.	Brill et al., aci Eisler 1989
				5,000 mg/kg			Termites did not avoid bait.	
Termites (*Copotermes formosanus*)	1987	Sodium molybdate	Edible filter paper	5% solution			100% mortality of workers within 24 hours	Yoshimura et al., aci Eisler 1989
Fire ants (*Solenopsis* sp), beetles, cockroaches	1987		In bait	5,000 mg/kg, 48 days	5,000 mg/kg			Brill et al., aci Eisler 1989

aci as cited in
bw body weight
d day
kg kilogram
L liter
LOAEL lowest observed adverse effect level
µg micrograms
mg milligrams
NOAEL no observed adverse effect level
ppm parts per million
USEPA U.S. Environmental Protection Agency

NOTE: mg/kg designates a concentration in feed, soil, or other medium; mg/kg bw designates a dose.

Table A-3

SUMMARY OF TOXICITY STUDIES OF MOLYBDENUM: LARGE HERBIVORES (LIVESTOCK, DEER)

Strain	Year of Publication	Form of Molybdenum	Route of Administration	Dose or Concentration in Food	NOAEL	LOAEL	Exposure Duration	Adverse Effects	Citation
Cattle	1972		In forage			5 ppm Mo plus 10 ppm Cu		Decreased weight gain, decreased fertility, delayed maturity	Thornton et al., aci USEPA 1979
Cattle	1966			10 mg/kg bw				Acute lethal dose	Cook et al., aci USEPA 1979
Cattle	1976		In forage	32 to 40 mg/kg		32 to 40 mg/kg		Diarrhea, emaciation, high mortality in calves; sterility in males, failure of oestrus in females, diarrhea, unthriftiness, altered hair color in mature animals	Hornick and Baker, aci CANMET 1994
Cattle (?)	1992		In hay		50 mg Mo/kg in feed plus 19 mg Cu/kg feed			No molybdenosis; downward trend in plasma copper levels	Mir et al., aci CANMET 1994
Male calves	1951		In diet	300 ppm 400 ppm (4 to 8 mg/kg bw)			130 days	Severe degeneration of seminiferous tubules; decreased libido	Thomas and Moss, aci USEPA 1979
Beef cattle	1987 (two papers)	Ammonium molybdate	In feed	0 mg/kg 5 mg/kg, plus 0 or 800 mg iron/kg low-copper diets			from weaning	Delayed oestrus (by 5-6 weeks), reduced conception rate, disrupted oestrus cycles, decreased release of luteinizing hormones, decreased food intake, altered iron metabolism, signs of copper deficiency	Phillippo et al., aci CANMET 1994, Eisler 1989, and McDowell et al. 1993
Lactating beef cattle	1987		In diet	0 mg/kg 20 mg/kg 40 mg/kg plus 6 mg Cu/kg		40 mg/kg	9 weeks	Decline in total plasma copper, trichloroactic acid soluble copper, and ceruloplasmin; non-statistically significant impact on milk production (30% reduction); milk Mo levels of 1.6 mg/L; growth reduction in nursing calves	Wittenberg and Devlin, aci CANMET 1994
Cattle and sheep	1975		In herbage	> 12 mg/kg dry weight				Problems expected in cattle; lesser problems in sheep	Friberg et al., aci Eisler 1989
Cattle and sheep	1986		In pasture	10 to 100 mg/kg dry weight				"teart pastures"	Friberg et al., aci Eisler 1989
Swiss beef cattle	1986			141 mg/d				Anorexia, diarrhea and weight loss	Friberg et al., aci Eisler 1989
Cattle	1987		In diet	< 5 mg/kg plus sufficient copper				Normal growth; 100% fertilization; normal development in 63% of embryos	O'Gorman et al., aci Eisler 1989
				15 to 20 mg/kg, copper deficient				Normal growth and fertilization; reduced liver copper; normal development in 16% of embryos	
Cattle	1971		In diet	30 mg/kg plus normal copper				Blood Mo levels of 0.6 to 0.8 mg/L	Underwood, aci Eisler 1989
				100 mg/d				Normal milk Mo level (0.06 mg/L)	
				500 mg/d				Milk Mo of 0.37 mg/L	
Cattle	1978		In diet	60 mg/kg dry weight				Low liver copper, intestinal disturbances, brittle (fracture-prone) bones	Penumarthy and Oehme, aci Eisler 1989
		Soluble molybdate		1,360 mg/d				Molybdenum poisoning	
Dairy herd	1976	Mo-contaminated magnesium oxide	Pelleted feed			140 mg/kg fresh weight plus 100 mg Cu/kg fresh weight		Molybdenosis	Lloyd et al., aci Eisler 1989

Table A-3

SUMMARY OF TOXICITY STUDIES OF MOLYBDENUM: LARGE HERBIVORES (LIVESTOCK, DEER)

Strain	Year of Publication	Form of Molybdenum	Route of Administration	Dose or Concentration in Food	NOAEL	LOAEL	Exposure Duration	Adverse Effects	Citation
5-week-old calves	1980	Ammonium molybdate	In water	0 mg/L 1 mg/L 10 mg/L	10 mg/L (0.07 mg/kg bw/d)			No effect on liver or plasma copper level	Kincaid, aci Eisler 1989 and WHO 1996
				50 mg/L (basal diet with 13 mg Cu/kg and 2,900 mg sulfur/kg)		50 mg/L	21 days	Reduced liver copper concentration (dry weight), elevated copper plasma level; no effect on growth, or food/water consumption	
Cattle	1979		--	10 mg/kg bw				Lethal dose	Chappell et al., aci Eisler 1989
Ewes	1988		In diet	0 mg/kg 20 mg/kg 40 mg/kg	40 mg/kg		6 weeks	No hypocuprosis or molybdenosis, body weight change, milk yield change, milk organic constituent change; Mo in milk increased with each increment	Wittenberg and Devlin, aci CANMET 1994
Ewes	1988	Heteathio-molybdate	Ingestion	0 mg/d 20 mg/d 60 mg/d				Evidence of copper depletion; placental transfer of Mo with limited Mo accumulation and reduced copper levels in fetal liver	Kincaid and White, aci CANMET 1994
Ewes and ewe lambs	1993		In diet	7 mg Cu/kg plus 0.9 mg Mo/kg, 1.4 g sulphur/kg **or** 13 mg Mo/kg, 3.5 g sulphur/kg	0.9 mg/kg	13 mg/kg		Mild molybdynosis; no impact on reproductive performance; higher weaning rates	Robinson, aci CANMET 1994
Sheep	1980		Pasture		0.4 to 1.5 mg/kg dry weight			No lameness or connective tissue lesions	Pitt et al., aci Eisler 1989
						5.5 to 12.5 mg/kg dry weight		Increased Mo concentrations (fresh weight) in plasma, liver and kidney; most sheep exhibit lameness and connective tissue lesions	
Lambs	1984		Diet	50 mg/kg				Avoidance	White et al., aci Eisler 1989
Lambs	1987		Ingestion			8 mg/day plus 36.3 mg Cu/d and 3.7 g sulfur/d	125 days	No effect on growth, food intake; increased liver Mo; response varied significantly across breeds	Harrison et al., aci Eisler 1989
Pregnant ewes	1979		Diet					Severe demyelinization in central nervous system and low liver copper levels in newborn lambs	Earl and Vish, aci Eisler 1989
Pregnant Cheviot ewes	1960	Ammonium molybdate	Diet			50 mg/d		Ataxia and demyelination of cerebral nervous system in newborn lambs, consistent with "swayback"	Mills and Fell, aci IMOA 2000 and WHO 1996
Deer	1976	--	In diet			1,000 to 7,000 ppm		Growth reduction	Ward and Nagy, aci USEPA 1979
Mule deer	1976	Sodium molybdate	In diet pellets (not similar to natural food)	50 to 7,500 mg/kg				Weight loss, death (4/7)	Ward and Nagy, aci CANMET 1994
White-tailed deer	1984		Forage grown near uranium strip mine					No molybdenosis, but copper deficiency not triggered by molybdenum	King et al.

Table A-3

SUMMARY OF TOXICITY STUDIES OF MOLYBDENUM: LARGE HERBIVORES (LIVESTOCK, DEER)

Strain	Year of Publication	Form of Molybdenum	Route of Administration	Dose or Concentration in Food	NOAEL	LOAEL	Exposure Duration	Adverse Effects	Citation
Deer and moose	Undated		Forage grown near molybdenum mine					Hair molybdenum levels in deer not affected by distance from mine; in moose, those collected within 10 km of site had higher hair Mo than those more distant	Mathieu and Thorpe, aci CANMET 1994
Female mule deer	1975; 1976; 1978; 1979		Feed	Up to 200 mg/kg			33 days	No visible effects	Nagy et al.; Ward and Nagy; Ward; Chappell; all aci Eisler 1989
				1,000 mg/kg	1,000 mg/kg		8 days	No visible effects	
						2,500 mg/kg	25 days	Reduced food intake and diarrhea	
				5,000 mg/kg			3 to 15 days	Pronounced signs, but immediate recovery upon return to uncontaminated feed	
				7,000 mg/kg			3 to 15 days	Pronounced signs, but immediate recovery upon return to uncontaminated feed	
Horse foals and yearlings	1981; 1987		Pasture	5 to 25 mg/kg				Bone disorders possibly related to Mo accumulation in liver	Cymbaluk et al.; Strickland et al.; both aci Eisler 1989
Horses, ponies	1971		Teart pastures					No effect	Underwood, aci Eisler 1989
Horses, ponies	1986	Molybdate	Single oral dose Mo-99 (20-28 mg)					Rapid uptake to, and clearing from, plasma	Goyer, aci Eisler 1989
			In diet	20 mg/kg dry weight for 4.5 months; sulfur-supplemented for 1 month				Healthy animals; no impact on copper status	
Horses, ponies	1987		In diet	Up to 107 mg/kg			14 days	Decreased copper retention; no obvious adverse effects	Strickland et al., aci Eisler 1989

aci as cited in
bw body weight
d day
kg kilogram
L liter
LOAEL lowest observed adverse effect level
µg micrograms
mg milligrams
NOAEL no observed adverse effect level
ppm parts per million
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NOTE: mg/kg designates a concentration in feed, soil, or other medium; mg/kg bw designates a dose.

Table A-4

SUMMARY OF TOXICITY STUDIES OF MOLYBDENUM: OTHER MAMMALS

Strain	Year of Publication	Form of Molybdenum	Route of Administration	Dose or Concentration in Food	NOAEL	LOAEL	Exposure Duration	Adverse Effects	Citation
Rats	1940	--	-			100 to 150 mg/kg bw		Acute lethal dose	Maresh et al., aci USEPA 1979
Rats	1965	--	In food			5,000 ppm		Death	Arrington et al., aci USEPA 1979
Rats	--	--	In food			2,500 ppm (force-feeding) (~ 50 mg/d)		100% mortality after 10 days -- acromotrichous anemia; white liver and kidney	USEPA 1979
Rats	1976	Molybdate	In drinking water	0 mg/L 10 mg/L 100 mg/L 1,000 mg/L		1,000 mg/L		Pups in second treated generation: stunting, rough hair, sterile males, hyperactivity (no effect on lifespan); reduced pup size; slightly smaller litters. No increased tumors, terata, still-born or resorbed fetuses.	Winston et al., aci USEPA 1979
Rats	1976	Molybdate	In drinking water (lifetime)	250 mg/L 1,000 mg/L				No severe symptoms	Winston et al., aci USEPA 1979
Rat	1948	Sodium molybdate	In food	500 ppm 800 ppm		500 ppm		Similar to Winston et al.	Neilands et al., aci USEPA 1979 and IMOA 2000
Rat	1948	Sodium molybdate	In food	50 ppm 100 ppm 250 ppm		50 ppm		Reduced growth rate; reduced litter size	Neilands et al., aci USEPA 1979 and IMOA 2000
Long-Evans rats	1954	Sodium molybdate	In diet from weaning	? 80 ppm		80 ppm (2 mg/kg bw/d)		Sterility in 75% of males	Jeter and Davis, aci USEPA 1979 and WHO 1996
				140 ppm		140 ppm		Seminiferous tubule degeneration	
Charles River CD Mice	1973, 1971		In water plus food	1 mg/L (water) plus 0.25 ppm (food)					
				10 mg/L (water) plus 0.25 ppm (food) (equivalent to 1.5 mg/kg bw/d); 3 generations	1 mg/L	10 mg/L		Increased young deaths and dead litters after 3 generations; failure to breed	Schroeder, aci USEPA 1979; and Schroeder and Mitchener*, aci USEPA 1979; Vyskočil and Viau 1999; and WHO 1996
Rats weighing less than 600 g	1979	Sodium molybdate	In water	5 mg/L		5 mg/L		Growth reduction	USEPA 1979
				10 mg/L (≈350 to 400 µg/d or 1.5 mg/kg bw/d)					
Rats weighing more than 600 g	1979	Sodium molybdate	In water	Up to 1,000 mg/L		1,000 mg/L		Growth reduction	USEPA 1979
Rat	1973		Drinking water			10 mg/L	3 years	Disrupted calcium metabolism	Solomons et al., aci Eisler 1989
Rat	1973 and 1976		Drinking water			10 mg/L	3 years	Increased sensitivity to cold stress; elevated tissue Mo levels (dry weight)	Winston et al., aci Eisler 1989
Rat	1979		Drinking water			50 mg/L	lifetime	Growth retardation	Chappell et al., aci Eisler 1989
						1,000 mg/L	lifetime	No severe signs in breeding adults; pups are stunted with rough hair, sterile males, hyperactive	

Table A-4

SUMMARY OF TOXICITY STUDIES OF MOLYBDENUM: OTHER MAMMALS

Strain	Year of Publication	Form of Molybdenum	Route of Administration	Dose or Concentration in Food	NOAEL	LOAEL	Exposure Duration	Adverse Effects	Citation
Rat	1975	Hexavalent Mo		10 mg Mo/d			up to 232 days	LD-25 to LD50	Friberg et al., aci Eisler 1989
		Calcium molybdate		100 mg Mo/d			up to 232 days	LD-50	
		MoO_3		125 mg Mo/d			up to 232 days	LD-50	
		Ammonia molybdate		333 mg Mo/d			up to 232 days	LD-50	
Rat	1984		Diet	50 mg/kg				Diet avoidance	White et al., aci Eisler 1989
Rat	1979 and 1971		Diet	80 mg/kg with 35 mg Cu/kg	80 mg/kg		lifetime	No measurable effects; this level with copper deficiency resulted in decreased growth and survival	Underwood, aci Eisler 1989
				500 mg/kg or 1,000 mg/kg plus 77 mg Cu/kg				Poor growth (see below)	
				500 mg/kg				Normal growth	
				1,000 mg/kg				Normal growth	
Rat	1979		Diet	100 mg/kg, lifetime				Reduced appetite, weight, growth; anemia, mandibular exostoses, bone deformities, liver and kidney histopathology, male sterility	Chappell et al., aci Eisler 1989
				5,000 mg/kg				Lethal in 2 weeks	
Rat	1975		Diet	400 mg/kg				Depressed growth, anemia, mandibular exostoses after 5 weeks; some deaths after lifetime	Friberg et al., aci Eisler 1989
Female rat	1990	Soluble molybdate	In water	0 mg/kg bw/d					Fungwe et al.*, aci Vyskoèil and Viau 1999
				0.91 mg/kg bw/d	0.9 mg/kg bw/d		9 weeks		
				1.6 mg/kg bw/d		1.6 mg/kg bw/d	9 weeks	Prolonged oestrus cycle, decreased gestation weight, effect on embryo genesis	
				8.3 mg/kg bw/d			9 weeks		
				16.7 mg/kg bw/d			9 weeks		
Male rat	1954	Sodium molybdate	Diet	2 mg/kg bw/d		2 mg/kg bw/d	13 weeks	Depressed growth	Jeter and Davies*, aci Vyskoèil and Viau 1999; and IMOA 2000
				8 mg/kg bw/d			13 weeks		
				14 mg/kg bw/d			13 weeks		
				70 mg/kg bw/d			13 weeks		
Rat	1956	Hydrogen molybdate	Diet	7.5 mg/kg bw/d (75 ppm)		7.5 mg/kg bw/d	6 weeks	Bone deformities (femur) growth inhibition	Miller et al.*, aci Vyskoèil and Viau 1999; IMOA 2000; and USEPA 2000
				30 mg/kg bw/d (300 ppm)			6 weeks		
Rat	1954	Sodium molybdate	Oral	2 mg/kg bw/d	2 mg/kg bw/d	2 mg/kg bw/d	13 weeks	Alopecia; achromotrichia	Jeter and Davies*, aci Vyskoèil and Viau 1999; and IMOA 2000
				8 mg/kg bw/d			13 weeks		
				14 mg/kg bw/d			13 weeks		
				70 mg/kg bw/d (?)		8 mg/kg bw/d	13 weeks	Growth depression in females; infertility in males	
Rat	1961	Sodium molybdate	Oral			50 mg/kg bw/d	5 weeks		Ostrom et al., aci Vyskoèil and Viau 1999; and IMOA 2000
Long-Evans rat	1960	Soluble molybdate	Oral			50 mg/kg bw/d	5 weeks (males) or 8 weeks (females)	Diarrhea	Cox et al., aci Vyskoèil and Viau 1999; and WHO 1996

Table A-4

SUMMARY OF TOXICITY STUDIES OF MOLYBDENUM: OTHER MAMMALS

Strain	Year of Publication	Form of Molybdenum	Route of Administration	Dose or Concentration in Food	NOAEL	LOAEL	Exposure Duration	Adverse Effects	Citation
Rat	1990	Soluble molybdate	Gastric intubation	40 mg/kg bw/d	40 mg/kg bw/d		8 weeks		Bompart et al.*, aci Vyskoèil and Viau 1999
				80 mg/kg bw/d		80 mg/kg bw/d	8 weeks	Nephrotoxicity, decreased body weight	
Female Wister rat	1996	Na_2MoO_4	Diet			500 ppm		Prolonged estrus cycle; lower peak FSH and lower serum E2	Igarza et al., aci IMOA 2000
Holtman rat	1956	Hydrogen molybdate	Diet	7.5 mg/kg bw/d		7.5 mg/kg bw/d		Enlarged femorotibial joint, thickening of epiphysis of femur and tibia, weight loss	Miller et al., aci WHO 1996
				30 mg/kg bw/d					
Breeding mouse	1979		Drinking water	10 mg/L				Decreased survival in F2 and F3 generations	Earl and Vish, aci Eisler 1989
Pregnant golden hamster	1979		--		100 mg/kg bw			No terata or embryo deaths; no effect on gestation or fertility	Earl and Vish, aci Eisler 1989
Guinea pigs	1945	--	--			250 mg/kg bw		Acute lethal dose	Fairhall et al., aci USEPA 1979
Guinea pig	1975	MoO_3	--	25 mg Mo/d				75% mortality	Friberg et al., aci Eisler 1989
		Calcium molybdate	--	200 mg Mo/d				25% mortality	
Guinea pig	1965	Soluble molybdate	Diet	0 mg/kg bw/d			8 weeks		
				8 mg/kg bw/d (200 mg/kg)			8 weeks	Loss of copper	Arthur*, aci Vyskoèil and Viau 1999; and USEPA 2000
				20 mg/kg bw/d (500 mg/kg)			8 weeks	Reduced growth	
				40 mg/kg bw/d (1,000 mg/kg)		40 mg/kg bw/d	8 weeks		
				80 mg/kg bw/d (2,000 mg/kg)		75 mg/kg bw/d	8 weeks		
Rabbits	1973	--	In food			5,000 ppm		Reduced thyroid function	Widjajakusuma et al., aci USEPA 1979
White rabbit	1979		In diet	100 mg/kg			lifetime	Reduced growth, hair loss, dermatosis, anemia, skeletal and joint deformities, decreased thyroxin	Chappell et al., aci Eisler 1989
				5,000 mg/kg			lifetime	Thyroid dysfunction	
White rabbit	1975		Diet	500 mg/kg	500 mg/kg		5 weeks	No obvious effects	Friberg et al., aci Eisler 1989
				1,000 mg/kg			12 weeks	Growth retardation	
				2,000 to 4,000 mg/kg				Deaths among weanlings in about 37 days and of adults in 53 days; survivors had anorexia, diarrhea, front leg abnormalities; recovery with Cu therapy	
				500 mg/kg				No deaths after 6 weeks; growth retardation and anemia	
				800 mg/kg				No deaths after 6 weeks; growth retardation and anemia	
Rabbit	1965	Soluble molybdate	Oral	0.025 mg/kg bw/d			6 months		
				0.5 mg/kg bw/d	0.5 mg/kg bw/d		6 months		
				5 mg/kg bw/d			6 months		
				50 mg/kg bw/d		5 mg/kg bw/d	6 months	Reduced growth, histopathology of liver and kidney	Asmangulyan, aci Vyskoèil and Viau 1999

Table A-4

SUMMARY OF TOXICITY STUDIES OF MOLYBDENUM: OTHER MAMMALS

Strain	Year of Publication	Form of Molybdenum	Route of Administration	Dose or Concentration in Food	NOAEL	LOAEL	Exposure Duration	Adverse Effects	Citation
Rabbit	1953	Sodium molybdate	Commercial ration	140 mg/kg			4 months		
				500 mg/kg			4 months		
				1,000 mg/kg			4 months		
				2,000 mg/kg	23 mg/kg bw/d		4 months		
				4,000 mg/kg		46 mg/kg bw/d	4 months	Anemia, reduced growth, skeletal anomalies	Arrington and Davies*, aci Vyskočil and Viau 1999; and IMOA 2000
Rabbit	1962	Soluble molybdate	Oral			25 mg/kg bw/d	5 weeks	Anemia, skeletal abnormalities	McCarter et al., aci Vyskočil and Viau 1999
Rabbit	1973	Soluble molybdate	Oral			66 mg/kg bw/d	1 month	Thyroid injury	Widjajakusuma et al., aci Vyskočil and Viau 1999
Pigs	1987		In feed	1,000 mg/kg	1,000 mg/kg				Mills and Davis, aci CANMET 1994
Pig	1971		Diet	1,000 mg/kg	1,000 mg/kg		3 months	No effects	Underwood, aci Eisler 1989

aci as cited in
bw body weight
d day
kg kilogram
L liter
LOAEL lowest observed adverse effect level
µg micrograms
mg milligrams
NOAEL no observed adverse effect level
ppm parts per million
USEPA U.S. Environmental Protection Agency
\- information not provided
* report specifically called out by Vyskočil and Viau as having good scientific design.

NOTE: mg/kg designates a concentration in feed, soil, or other medium; mg/kg bw designates a dose.

Table A-5

SUMMARY OF TOXICITY STUDIES OF MOLYBDENUM: BIRDS

Strain	Year of Publication	Form of Molybdenum	Route of Administration	Dose or Concentration in Food	NOAEL	LOAEL	Exposure Duration	Adverse Effects	Citation
Chicks	1987		in feed	Up to 2,000 mg/kg		200 mg/kg		Mild growth depression	Mills and Davis, aci CANMET 1994
Day-old chicks	1977	Molybdenum mine tailings	Diet	20% of diet 40% of diet	20%	40%	23 days	Slight reduction in bw	Kienholz, aci Eisler 1989
Chicks	1975		Diet	500 mg/kg			4 weeks	Slight decrease in growth rate	Friberg et al., aci Eisler 1989
Hens	1975		Diet	500 mg/kg		500 mg/kg		15% fewer eggs laid; eggs had embryolethal concentrations of 16 to 20 mg molybdenum/km	Friberg et al., aci Eisler 1989
				1,000 mg/kg		1,000 mg/kg		Egg production reduced 50%	
				2,000 mg/kg				80% reduction in egg production	
Chicks	1971		Diet	6,000 mg/kg			4 weeks	33% mortality	Underwood, aci Eisler 1989
			Diet	8,000 mg/kg			4 weeks	61% mortality; survivors weigh 16% as much as controls	
			Diet	200 mg/kg		200 mg/kg		Minor growth inhibition	
			Diet	2,000 mg/kg				Severe growth depression and 100% increase in molybdenum content of tibia	
			Diet	4,000 mg/kg				Severe anemia	
4- and 8-day old chick embryos	1952	Sodium molybdate	Injection to yolk sac					No embryotoxicity	Ridgway and Karnofsky, aci IMOA 2000
Turkey poults	1971		Diet	300 mg/kg		300 mg/kg		Growth reduced	Underwood, aci Eisler 1989

aci — as cited in
bw — body weight
d — day
kg — kilogram
L — liter
LOAEL — lowest observed adverse effect level
µg — micrograms
mg — milligrams
NOAEL — no observed adverse effect level
ppm — parts per million
USEPA — U.S. Environmental Protection Agency
\- — information not provided

NOTE: mg/kg designates a concentration in feed, soil, or other medium; mg/kg bw designates a dose.

PHOTOGRAPHS

Photo 1. Piñon-Juniper woodland habitat adjacent to the Questa Tailings Facility.

Photo 2. Piñon-Juniper habitat west of the Tailings Facility (looking towards the Guadalupe Mountains).

Photo 3. Sagebrush community adjacent to Tailings Facility.

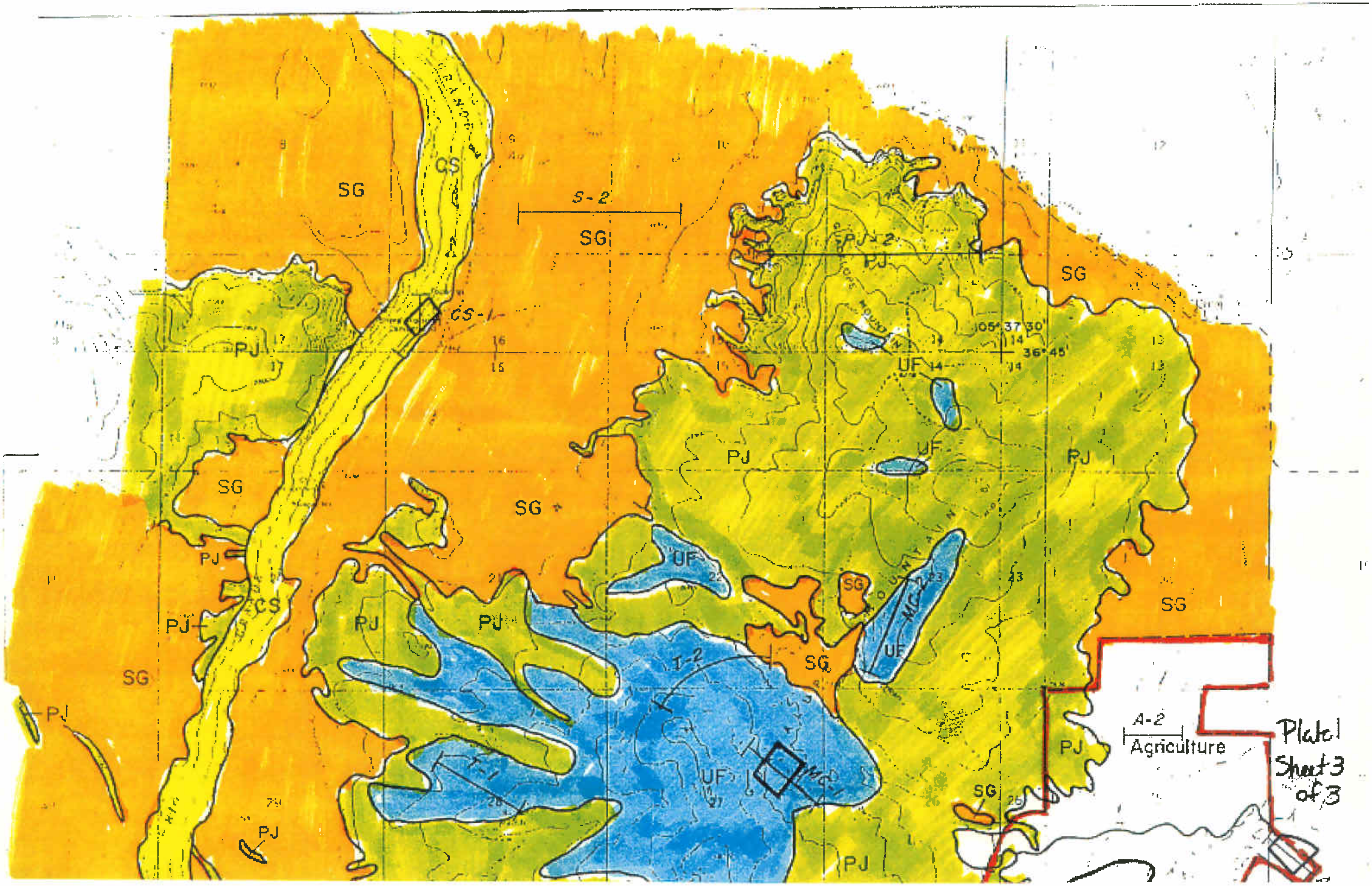
Photo 4. Sagebrush and Piñon-Juniper community trasition zone at the Tailings Facility.

Photo 5. Grassland/ Sagebrush community adjacent to Tailings Facility.

Photo 6. Interim revegetation at the Tailings Facility. Area seeded in 1993-94, shrubs invaded naturally and are rabbitbrush and sagebrush.

Photo 7. Interim revegetation at the Tailings Facility. Seeded in 1993-94, photo taken September, 2000.

PLATES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Agriculture
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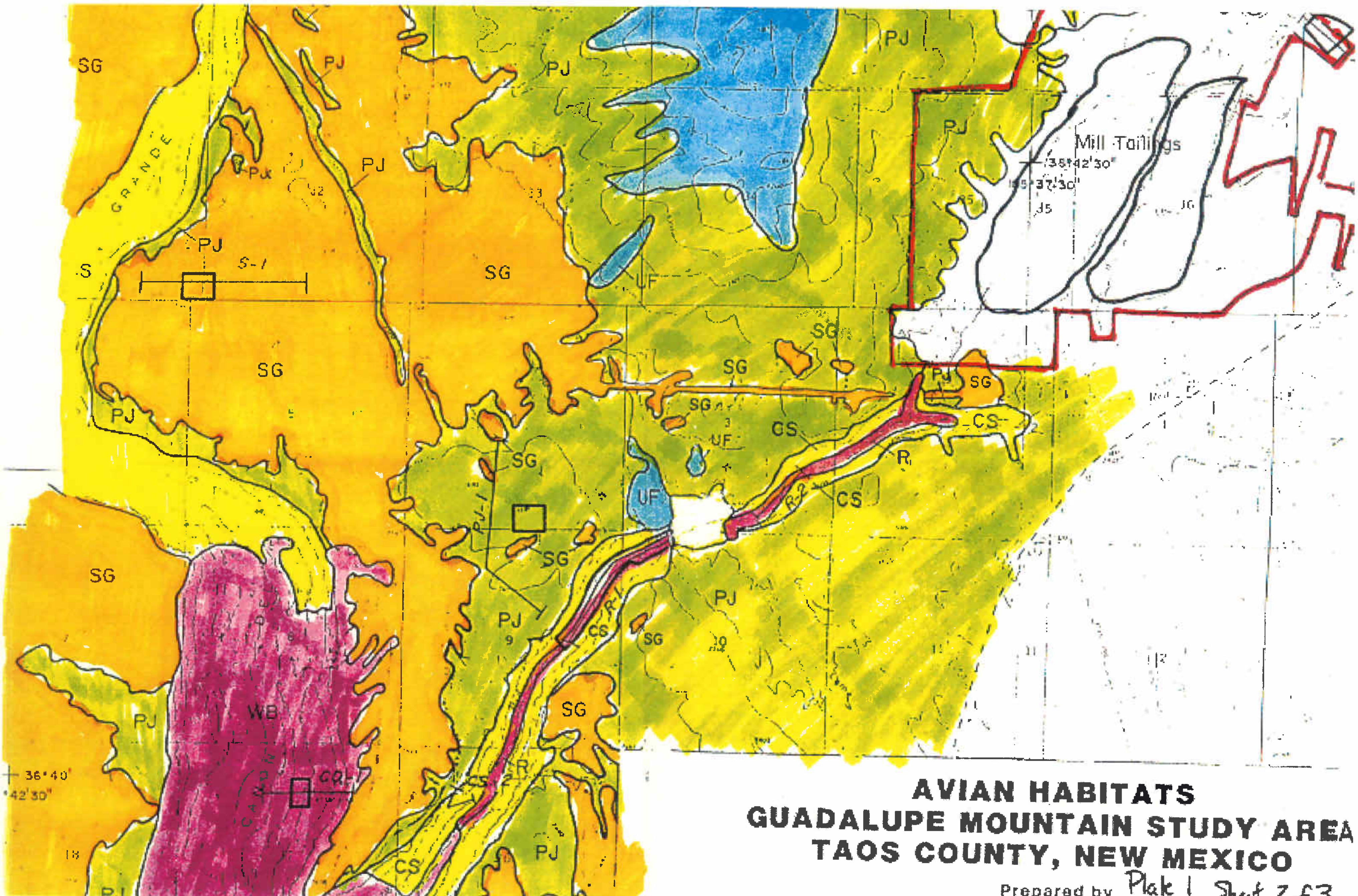
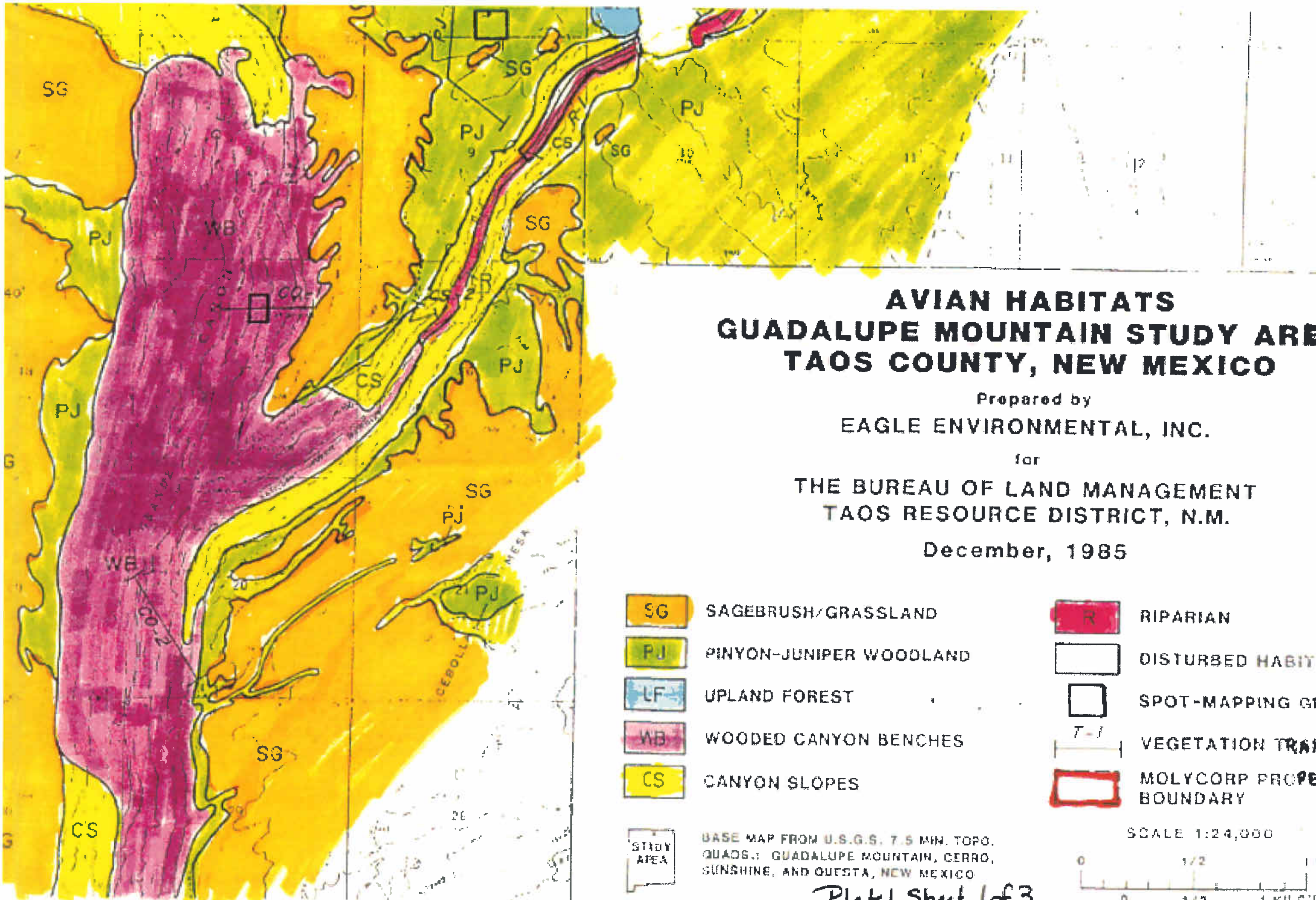
Plate I
Sheet 3
of 3



AVIAN HABITATS
GUADALUPE MOUNTAIN STUDY AREA
TAOS COUNTY, NEW MEXICO

Prepared by Plate I Sheet 2 of 3



AVIAN HABITATS
GUADALUPE MOUNTAIN STUDY AREA
TAOS COUNTY, NEW MEXICO

Prepared by

EAGLE ENVIRONMENTAL, INC.

for

THE BUREAU OF LAND MANAGEMENT
TAOS RESOURCE DISTRICT, N.M.

December, 1985

SG	SAGEBRUSH/GRASSLAND	R	RIPARIAN
PJ	PINYON-JUNIPER WOODLAND		DISTURBED HABIT
UF	UPLAND FOREST		SPOT-MAPPING GRID
WB	WOODED CANYON BENCHES	T-1	VEGETATION TRANSECT
CS	CANYON SLOPES		MOLYCORP PROPERTY BOUNDARY

STUDY AREA

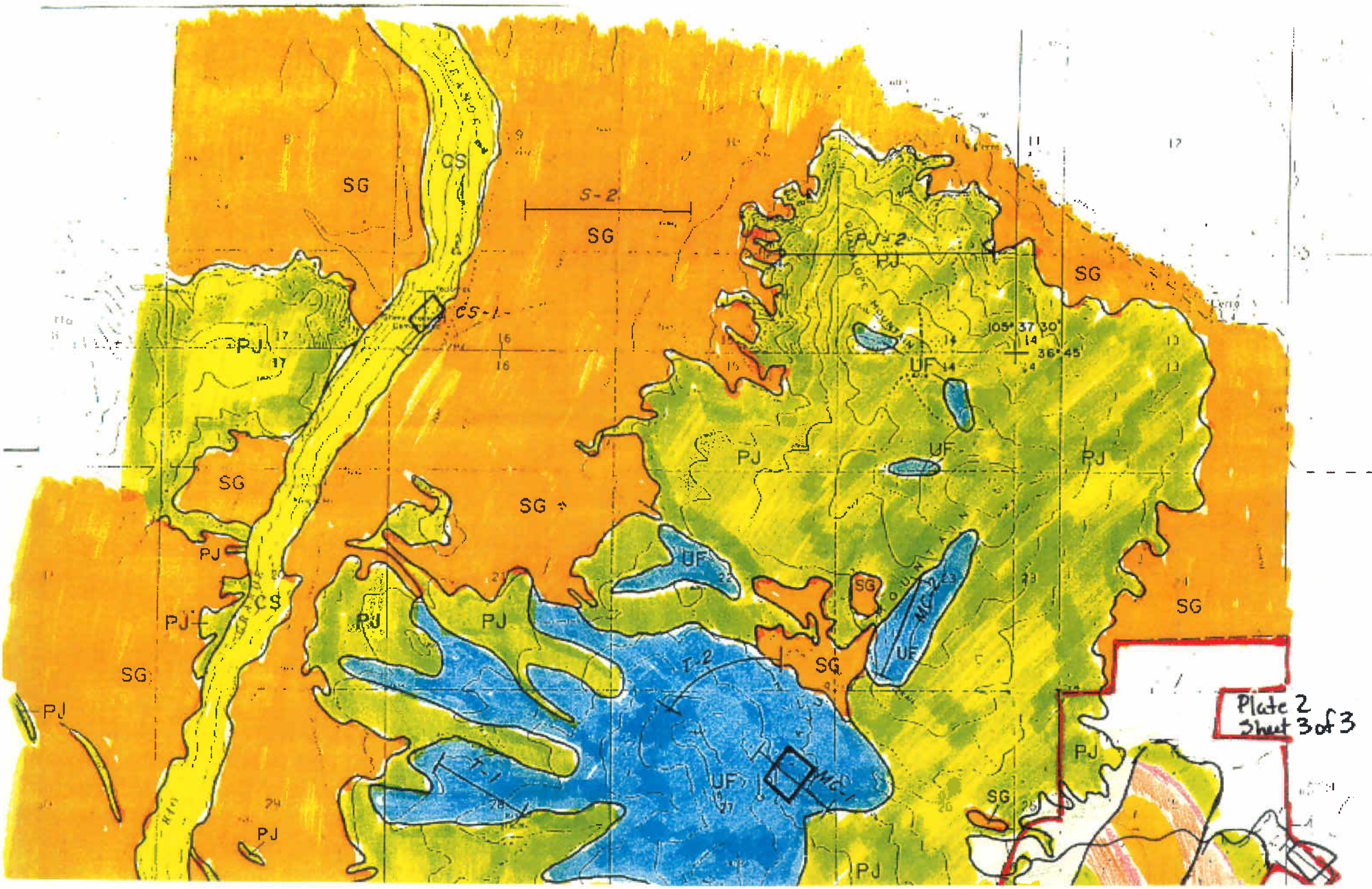
BASE MAP FROM U.S.G.S. 7.5 MIN. TOPO. QUADS.: GUADALUPE MOUNTAIN, CERRO, SUNSHINE, AND QUESTA, NEW MEXICO

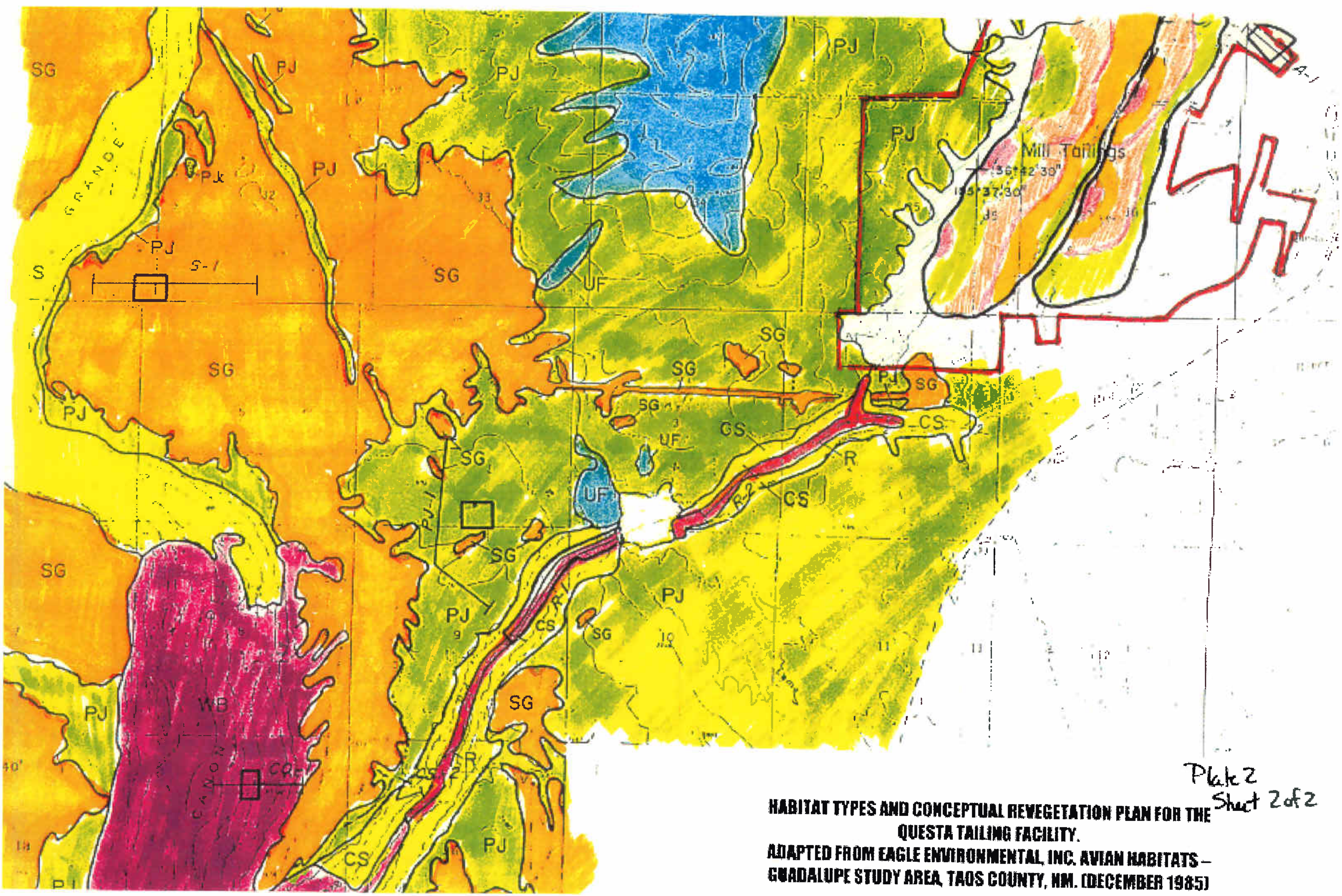
SCALE 1:24,000

0 1/2 1

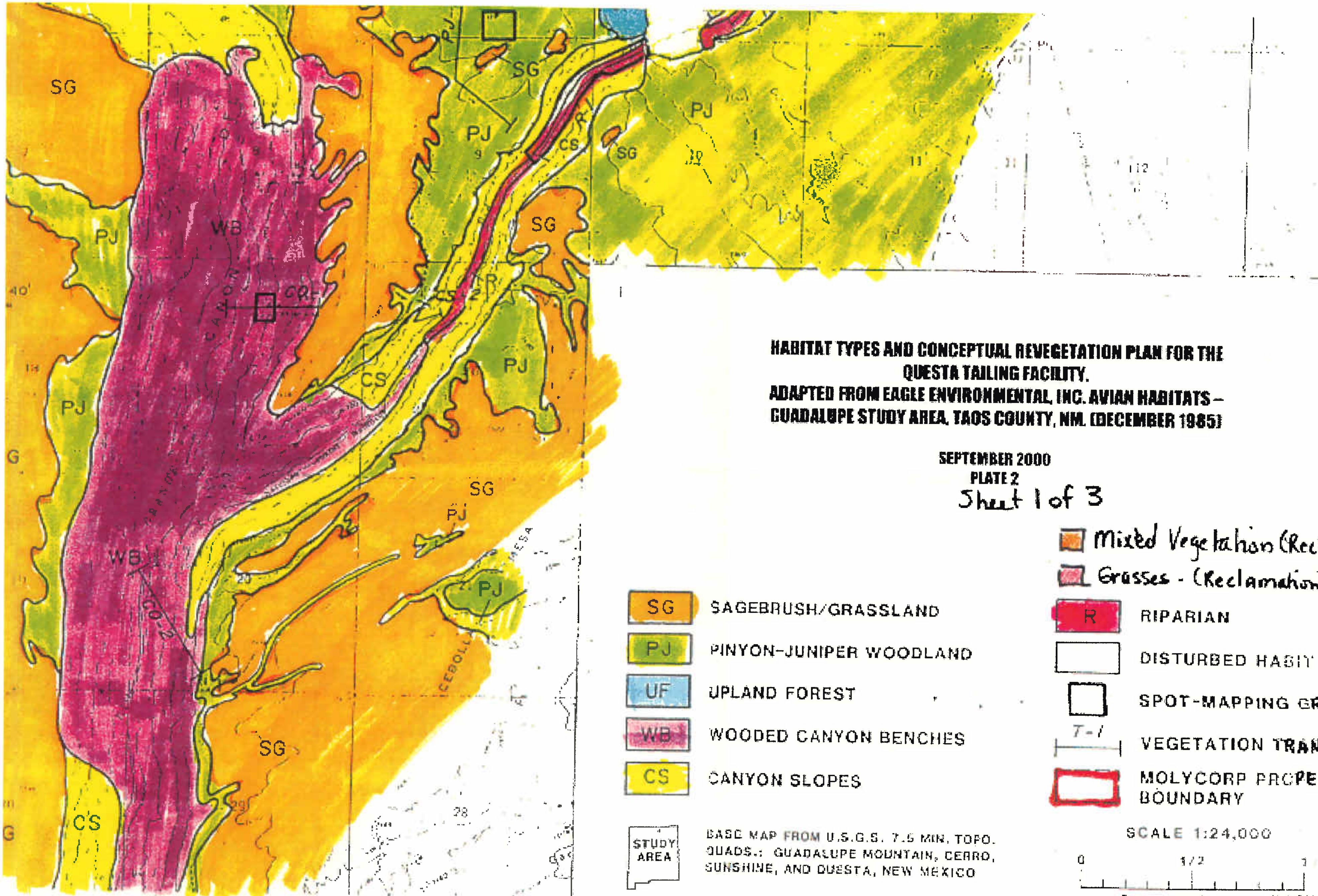
0 1/2 1 KILO

Plate 1 Sheet 1 of 3


SG
CS
S-2
CS-1
PJ
PJ-2
UF
MC-2
T-2
T-1
MC-1
105° 37' 30"
36° 45'
Plate 2
Sheet 3 of 3



HABITAT TYPES AND CONCEPTUAL REVEGETATION PLAN FOR THE QUESTA TAILING FACILITY.
ADAPTED FROM EAGLE ENVIRONMENTAL, INC. AVIAN HABITATS – GUADALUPE STUDY AREA, TAOS COUNTY, NM. (DECEMBER 1985)



HABITAT TYPES AND CONCEPTUAL REVEGETATION PLAN FOR THE QUESTA TAILING FACILITY.
ADAPTED FROM EAGLE ENVIRONMENTAL, INC. AVIAN HABITATS – GUADALUPE STUDY AREA, TAOS COUNTY, NM. (DECEMBER 1985)

SEPTEMBER 2000
PLATE 2
Sheet 1 of 3

- SG — SAGEBRUSH/GRASSLAND
- PJ — PINYON-JUNIPER WOODLAND
- UF — UPLAND FOREST
- WB — WOODED CANYON BENCHES
- CS — CANYON SLOPES
- Mixed Vegetation (Reclam.)
- Grasses - (Reclamation)
- R — RIPARIAN
- DISTURBED HABIT
- SPOT-MAPPING GRID
- T-1 — VEGETATION TRANSECT
- MOLYCORP PROPERTY BOUNDARY

STUDY AREA

BASE MAP FROM U.S.G.S. 7.5 MIN. TOPO. QUADS.: GUADALUPE MOUNTAIN, CERRO, SUNSHINE, AND QUESTA, NEW MEXICO

SCALE 1:24,000
0 1/2 1
0 1/2 1 KILOM