# COMPREHENSIVE COVER PERFORMANCE EVALUATION

## STOCKPILES AND TAILING IMPOUNDMENTS

## DP-1341 CONDITION 75
## AND
## CONDITION 31 OF DP-27
## SETTLEMENT AGREEMENT

*Submitted to:*

*Phelps Dodge Tyrone Inc.*
*P.O. Drawer 571*
*Tyrone, NM 88065*

*Submitted by:*

*Golder Associates Inc.*
*4910 Alameda Blvd., Suite A*
*Albuquerque, NM 87113*

Distribution

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## 1.0 INTRODUCTION

The Tyrone Mine is an open pit copper mine and solution extraction-electrowinning (SX/EW) facility near Silver City, New Mexico (Figure 1). Phelps Dodge Tyrone Inc. (Tyrone) is evaluating reclamation options with respect to meeting pertinent applicable requirements of the New Mexico Water Quality Control Act (WQA), the Water Quality Control Commission (WQCC) Regulations, and the New Mexico Mining Act. Tyrone is permitted as an existing mine (No. GR010RE) with the New Mexico Mining and Minerals Division (MMD).

Golder Associates Inc. (Golder) conducted studies to address requirements of Condition 75 of the Supplemental Discharge Permit for Closure, DP-1341 and Paragraph 31 of the Discharge Permit DP-27 Settlement Agreement (NMED, 2003a and 2003b). In addition, these studies provide information relevant to closeout issues regulated by the MMD. Condition 75 of DP-1341 and Condition 31 of the DP-27 Settlement Agreement require the completion of a Comprehensive Cover Performance Evaluation (CCPE) for the Tyrone Mine. As indicated in DP-1341, the purpose of the CCPE is to:

> *"…evaluate the type and thickness of the proposed cover materials and to further characterize the physical and hydraulic properties of the proposed cover materials for the Leach Ore Stockpiles and Waste Rock Piles. The study shall be designed to determine whether the cover described in this Supplemental Discharge Permit and/or alternative cover systems will ensure that the requirements of the WQA and WQCC Regulations are met. The study shall include an evaluation of the feasibility of limiting infiltration through the required covers or alternative covers to 1percent or less of mean annual precipitation in conjunction with the study required in Condition 89. The evaluation shall include, at a minimum, a prediction of post-closure impacts of Leach Ore Stockpile and Waste Rock Pile seepage to ground water quality based on a calibrated soil atmosphere model, calibrated ground water flow model(s), and geochemical modeling."*

Condition 31 of DP-27 requires that Tyrone "evaluate the type and thickness of proposed cover materials and to further characterize the physical and hydraulic properties of the proposed cover materials for the [Mangas Valley] tailing impoundments" (NMED 2003b). In addition, Condition 79 of DP-1341 requires Tyrone to revise the borrow source materials investigation for the Leach Ore Stockpiles and Waste Rock Piles "to consider the data needs for the cover performance evaluation in Condition 75." These evaluations are linked to the feasibility study under Condition 89 of DP-1341 to predict post-closure impacts of leach ore, waste rock or tailing seepage to ground water quality

# STATE OF NEW MEXICO

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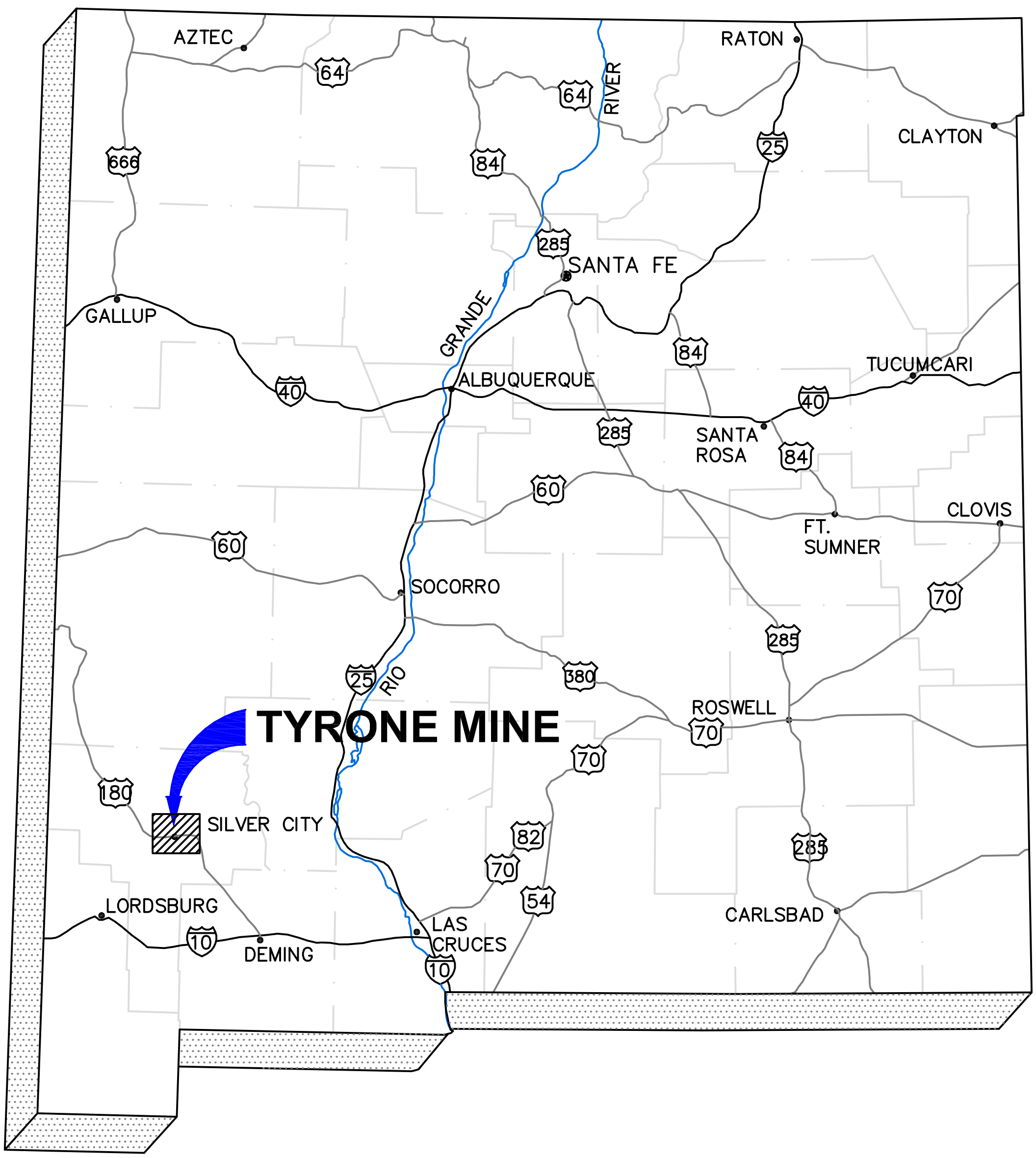


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based on a calibrated soil-atmosphere model. Thus, common data requirements for the soil-atmosphere model, particularly key model-input parameters associated with plants, will be collected and integrated to meet the requirements of these various permit conditions.

According to Condition 17 of DP-1341, the proposed cover for the waste rock piles and leach ore stockpiles is a store-and-release type that consists of a minimum of 36 inches of alluvium (e.g. Gila Conglomerate) or other non-acid generating materials approved by NMED. According to the Condition 23 of the DP-27 Settlement Agreement, the cover for the Mangas Valley Tailing Impoundments is a store and release cover system, consisting of a minimum of 24 inches of alluvium (e.g., Gila Conglomerate Formation) or other non-acid generating material approved by NMED. Based on the results of the CCPE and other applicable studies, alternative cover designs may be proposed if the performance of the alternative cover is equivalent to the proposed cover. Alternative covers being evaluated by PDTI include 24- and 48-inch thick store-and-release covers for the Waste Rock Piles and Leach Ore Stockpiles, and 18-, 36-, and 48-inch thick store-and-release covers for the tailing impoundments. The covers will be composed of earthen materials from nearby Gila Conglomerate, overburden, leach cap oxide materials from the Little Rock project and the Copper Mountain Pit expansion, as well as local alluvial materials.

### 1.1 Goals

Ultimately, the CCPE will use information generated in association with Conditions 76 (Cover, Erosion, and Revegetation Test Plot Study), 79 (Borrow Source Material Investigation), and 89 (Feasibility Study) of DP-1341, Condition 29 of the DP-27 Settlement Agreement, and other studies to complete a comprehensive evaluation of the effectiveness of the cover designs. The studies and assessments in Conditions 75, 76 and 89 of DP-1341, and Condition 29 of the DP-27 Settlement Agreement are intricately interrelated in the closure planning process as discussed in more detail in Section 6. In the near-term, the results of the CCPE will be used to support studies required in Condition 89 of DP-1341 and the development of the Cover, Erosion, and Revegetation Test Plots required in Condition 76 of DP-1341 (NMED 2003a) and Condition 29 of the DP-27 Settlement Agreement (NMED 2003b).

The primary emphasis of this report is to validate the input parameters that have been used in the water-balance models for the Tyrone Mine (DBS&A 1999a). Thus, information was collected on the physical and hydraulic characteristics of the cover materials and leaf area indices and root distributions of the native plants within the reference areas at Tyrone. The period of record for the climatic simulations was expanded from 10 to 100 years to include increased variability and more normal conditions than the initial assessments. More specifically, the CCOE efforts include:

1) Refined the leaf area index (LAI) functions used in the soil-atmosphere modeling based on data collected during field studies (Section 2)
2) Refined the root length density (RLD) functions used ion the soil-atmosphere modeling based on data collected during field studies (Section 3)
3) Compiled and reviewed existing cover materials characterization data (Section 4)
4) Performed long-term (100-year) UNSAT-H simulations incorporating the revised LAI and RLD functions (Section 5)

Section 6 provides a strategy for the integration of the CCPE information with related permit conditions required by the MMD and NMED.

## 2.0 LEAF AREA INDEX

Plant leaves and other photosynthetic organs serve to collect solar energy and exchange gases, transferring energy between plant canopies and the atmosphere. Transpiration, the movement of water from a plant to the atmosphere, is a passive process where atmospheric demand created at the leaf surface provides the energy needed to extract water from the soil. When a plant canopy is actively growing, transpiration is usually the dominant means of water loss from the soil profile (Hillel, 1998).

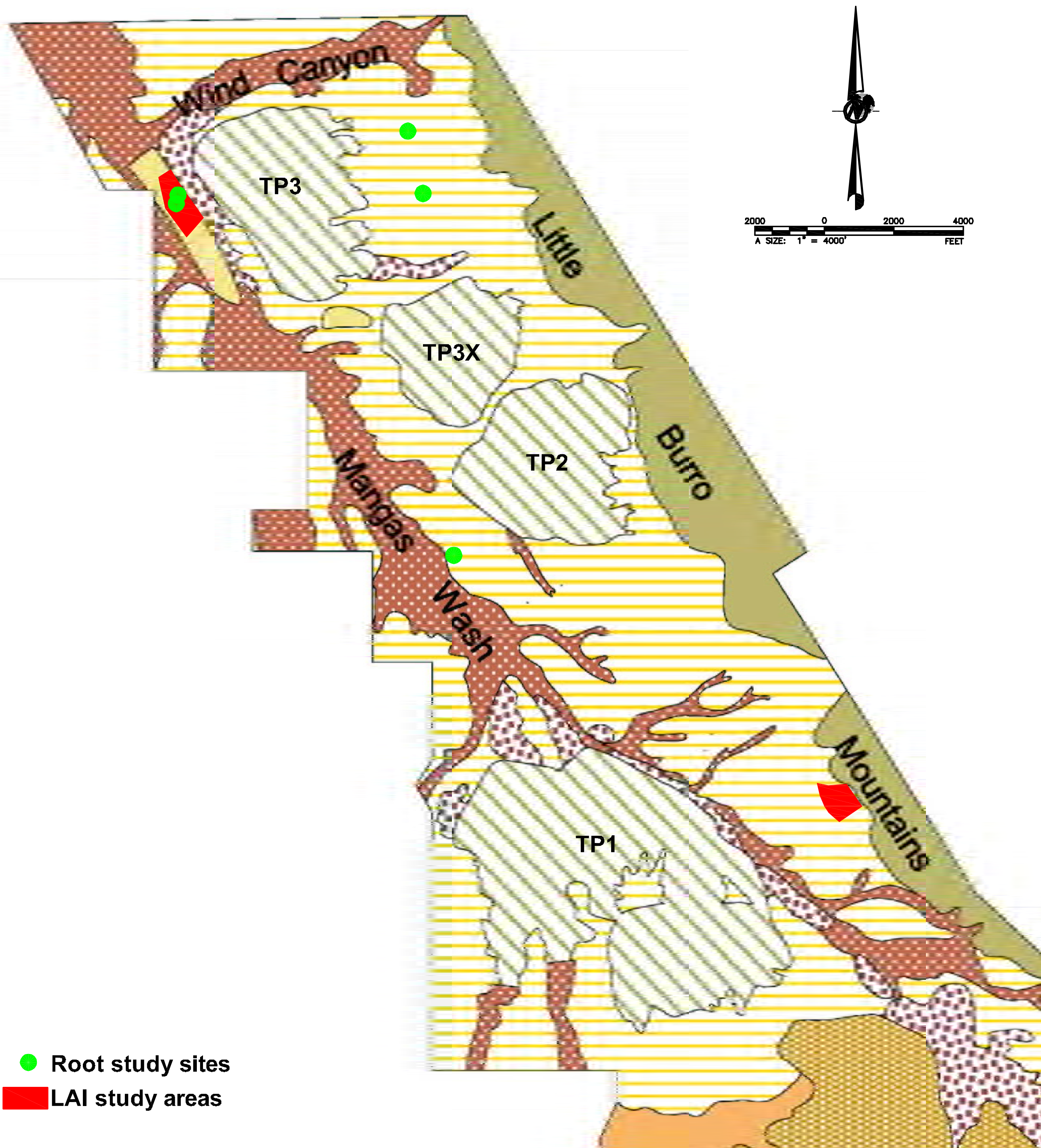
Leaf area index (LAI) is a key component in quantifying the transfer of energy in soil-water balance models. LAI is defined as the one-sided green foliage area-per-ground area (Scurlock et al., 2001; Campbell and Norman, 1998). It may be measured and/or described on a species or plant community basis. The LAI distribution describes the ratio of leaf surface area to the soil surface that the leaves cover throughout the year.

UNSAT-H can use daily LAI values to simulate changes in active photosynthetic tissue throughout the year. This investigation sought to determine the maximum leaf area that corresponds to the highest transpiration capacity of the reclaimed plant community.

### 2.1 Field Methods

Leaf area data were derived from the native piedmont scrub savanna plant community in the approved Tyrone Reference Area and a 20 year-old revegetated area on the South Main tailing repository (Figure 2-1). These areas were selected because the vegetation best represents the expected reclaimed shrub/grass plant community in the post-closure period.

A systematic random sampling procedure employing a transect/quadrat system was used to select sample sites within the two study areas. A 50 $ft^2$ grid was imposed over each study area to delineate vegetation sample plots and random coordinates were used to select plots for vegetation sampling (Appendix A). Originating from the southeast corner of the selected vegetation plot, a 30 m transect in a dog-leg pattern was established (DBS&A, 1999b). Two to four 0.25 $m^2$ quadrats were placed at predetermined intervals along the transect for quantitative vegetation measurements and plant tissue collection. A total of 8 plots (32 quadrats) were sampled in the Tyrone reference area and 7 plots (16 quadrats) were sampled at the tailing repository. Measured soil depths in the repository sampling area ranged from 15 to 25 inches.




Explanation

- Alluvial grassland
- Piedmont scrub savanna
- Mountain slope scrub savanna
- Mountain slope mixed evergreen woodland
- Facilities and disturbed areas
- Mine pits and stockpiles
- Reclaimed tailing
- Tailing ponds

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PROJECT

phelps dodge TYRONE Inc.

PHELPS DODGE TYRONE INC.
GRANT COUNTY, NEW MEXICO

TITLE

**CCPE STUDY AREAS & SOIL-VEGETATION ASSOCIATIONS MANGAS VALLEY-TYRONE MINE**

Golder Associates
Albuquerque, New Mexico

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Field work was conducted at the end of the growing season, but prior to the first killing frost (October 2004). Quantitative vegetation data (e.g. canopy cover, basal cover, and frequency) were collected using the methods approved by the MMD. Plant frequency was determined on a species-basis by counting the number of individual plants in the quadrat. Relative and total canopy cover, basal cover, surface litter, rock fragments and bare soil were visually estimated. Percent area cards were used to increase the accuracy and consistency of the cover estimates. In this study, canopy cover was defined as the percentage of the quadrat area included in the vertical projection of the canopy. The canopy cover estimates included the foliage and foliage interspaces of all the individuals rooted in the quadrat. The canopy cover estimates made on a species basis represent relative canopy cover and the sum of the total canopy cover, surface litter, rock fragments and bare soil and did not exceed 100 percent. Basal cover was defined as the portion of the ground occupied by the crowns of grasses and rooted stems of forbs and shrubs. In addition, basal cover estimates were made for surface litter, rock fragments and bare soil. Like total cover estimates, the sum of the basal cover estimates was 100 percent.

Following the estimation of vegetation parameters, each species in the vertical projection of the quadrat was clipped to within about 0.5 cm of the ground surface and placed into separate plastic bags. In cases where indvidual plant species in a quadrat contributed less the 0.1 percent basal cover they were grouped by form (e.g., forbs) and placed into a single bag. Bags were kept cool and out of the sun to maintain freshness until they could be transferred to a refrigerator. Field sheets and photographs of the sampling sites are provided in Appendix A.

## 2.2 Laboratory Analysis

Within one week of collection, all plant samples were removed from the bags and pressed to preserve the plant materials. After drying, a botanist separated photosynthetic (leaves) and nonphotsynthetic tissues (e.g., stems and flowers). In addtion, decadent leaf tissue representing last years growth was removed from the samples. The remaining leaf materials were then arranged on white paper to minimize overlap.

Black-and-white digital images were taken of each sample. Each picture was backlit to reduce shadows and glare, providing a clear image for digital analysis. Round 1.83 $cm^2$ and square 7.5 $cm^2$ standard scales were photograph with each plant sample to allow estimation of error due to lens distortion and camera angle.

Digital photos were processed using Paint Shop Pro 9.0 (Jasc Software) to improve contrast using a standardize script and to reduce photos to a representative two-color (1-bit) bitmap image. For each bitmap image, the number of pixels corresponding to the standard scales and leaf area were determined using the software's histogram function. A LAI value was then calculated for each sample and totaled for each quadrat.

## 2.3 Results

The UNSAT-H conceptual model for transpiration relies on an estimate of potential evapotranspiration (PET) that is calculated from meteorological data. The model applies a user-defined annual distribution of LAI to modify the potential rate of transpiration during the simulation and partition the removal of water by transpiring plants and/or vapor diffusion (Fayer, 2000). For each day in the model domain, the transpiration rate is applied to specific depths in the soil profile based on the fraction of roots described by the RLD equation (Section 3). Accordingly, more water is extracted from the soil profile as leaf area increases. Thus, understanding the extent and seasonal distribution of leaf area is important for validating the LAI function used in the soil-atmosphere model applied at Tyrone.

### 2.3.1 Peak LAI

Peak LAI values were calculated by averaging individual quadrat LAI for each study area (Table 2-1). The reclaimed plant community at the tailing repository had an average LAI of 0.29 and the native vegetation in the reference area had an average LAI of 0.42. Overall, LAI ranged from 0.11 to 0.56 for the reclaimed plant community and between 0.13 to 1.23 in the reference area. The generally higher individual and and average LAI values in the reference area result because shrubs were encountered more often than in the repository sample plots. While there was little difference in average canopy cover between reference and repository sites (Table 2-1); shrub densities were higher in the reference area. Quadrats with shrubs typically had LAI values greater than 0.5, which tended to increase the average values in the reference area. Shrubs occur on the repository but none were encountered in the sample quadrats.

The LAI estimates for Tyrone are generally consistent with published LAI values for similar plant communities (Table 2-2). Higher values in some of the other studies probably reflect the use of light interception measurement techniques, which tend to include non-photosynthetic plant organs (stems) in their estimate of LAI. Additionally, much of the current regional research is part of large-scale remote sensing studies that attempt to correlate satellite absorption and reflectance data with radiation measurements in the field.

Within the context of this study, LAI estimates may be affected by a number of factors. Sample preparation and pressing ultimately resulted in leaf overlap, dessication, and folding. Leaf overlap in the digital images resulted in 10 to 20 percent relative error, particularly in large samples. The overlap and inrtersection of leaves resulting in underestimating leaf area and was most pronounced in the higher leaf area samples. No corrections were applied to account for the shrinkage and folding (curling of cylindrical leaves). Many plants have other herbaceous photosynthetic tissues (e.g. green twigs; grass stems) that have the capacity to transpire water vapor, but we excluded these in the interest of conservatism. These factors likely reduced the total leaf area to varying degree depending on the species and size of sample. Despite near normal precipitation at Tyrone in 2004, the region has been subject to a prolonged drought for the past 5 years. Thus, the plant communities we measured may not fully reflect the long-term average condition in the area.

For both study areas, average LAI was lower than the original estimate of 0.5 used in previous water balance simulations. The LAI estimates presented here may be modified upon further review of technical information associated with other regional studies, closer examination of the Tyrone's leaf area datasets, and the completion of the LAI dataset being developed for Chino Mines Company as part of Contion 81, DP-1340 (NMED 2003c).

**TABLE 2-1**
**SUMMARY OF LAI VALUES AND CANOPY COVER FROM THE TYRONE STUDY AREAS.**

| Study Area /Plot | LAI | | | | | Canopy Cover % (CC) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Quadrat | | | | | Quadrat | | | |
| | A | B | C | D | | A | B | C | D |
| **Tailing Repository Exclusion Area (EA)** | | | | | | | | | |
| 1 | 0.11 | ns | 0.18 | ns | | 13 | ns | 23 | ns |
| 2 | 0.37 | ns | 0.32 | 0.51 | | 27 | ns | 39 | 47 |
| 3 | 0.25 | ns | 0.32 | ns | | 25 | ns | 29 | ns |
| 4 | 0.11 | ns | 0.12 | 0.48 | | 22 | ns | 16 | 80 |
| 5 | 0.34 | ns | 0.33 | ns | | 90 | ns | 66 | ns |
| 6 | 0.13 | ns | 0.20 | ns | | 18 | ns | 20 | ns |
| 7 | 0.56 | ns | --[a] | ns | | 85 | ns | 16 | ns |
| *Average LAI 0.29 ± 0.15* | | | | | | *Average CC 38.4 ± 26.7* | | | |
| **Tyrone Reference Area (TR)** | | | | | | | | | |
| 1 | 0.13 | 0.20 | 0.12 | 0.89 | | 6 | 49 | 14 | 97 |
| 2 | 0.50 | 0.32 | 0.37 | 0.72 | | 35 | 30 | 25 | 28 |
| 3 | 0.20 | 1.23 | 0.65 | 0.32 | | 8 | 100 | 100 | 15 |
| 4 | 1.23 | 0.40 | 0.33 | 0.54 | | 85 | 30 | 28 | 95 |
| 5 | 0.46 | 0.40 | 0.17 | 0.32 | | 43 | 62 | 15 | 24 |
| 6 | 0.47 | 0.20 | 0.29 | 0.30 | | 38 | 20 | 25 | 37 |
| 7 | 0.46 | 0.28 | 0.38 | 0.27 | | 40 | 27 | 38 | 25 |
| 8 | 0.45 | 0.20 | 0.28 | 0.33 | | 82 | 30 | 33 | 37 |
| *Average LAI 0.42 ± 0.27* | | | | | | *Average CC 41.3 ± 16.5* | | | |

[a] sample incomplete
ns - not sampled

**TABLE 2-2**
**PUBLISHED VALUES FOR LAI FROM SEMI-ARID PLANT COMMUNITIES**
**IN THE WESERN UNITED STATES.**

| Plant Community | Dominant Species | LAI | State | Method | Source |
|---|---|---|---|---|---|
| Peidmont scrub savanna | *Bouteloua/Hilaria/Aristida* | 0.13-1.23 | New Mexico | direct | Tyrone Study |
| Reclaimed grassland | *Bouteloua spp.* *Aristida spp.* | 0.11-0.56 | New Mexico | direct | Tyrone Study |
| Shrub steppe | *Larrea tidentata* *Bouteloua eriopoda* | 0.8-1.9 | New Mexico | allometry | Asner, 1998 |
| Desert grassland | *Bouteloua eripoda* | 0.8-3.8 | New Mexico | NA | Asner, 1998 |
| Desert shrubland | *Prosopis glandulosa* | 0.9-3.9 | New Mexico | NA | Asner, 1998 |
| Sub-tropical savanna | *Aristida/ Stipa/ Bouteloua* | 0.8-4.7 | Texas | NA | Asner, 1998 |
| Desert scrub | *Carnegiea/Cercidium/Prosopis* *Muhlenbergia/Arisitida* | 0.93 | Arizona | light meter | Whittaker and Niering, 1975 |
| Open oak woodland | *Quercus* *Muhlenbergia/Bouteloua/Aristida* | 1.76 | Arizona | light meter | Whittaker and Niering, 1975 |
| Desert grassland | *Bouteloua curtipendula* | 1.58 | Arizona | light meter | Whittaker and Niering, 1975 |
| Wyoming big sagebrush | *Artemesia tridentata* *Agropyron/Poa* | 0.13-0.34 | Idaho | point | Clark and Seyfried 2001 |
| Low sagebrush | *Artemesia arbuscula* *Poa secunda* | 0.03-0.53 | Idaho | point | Clark and Seyfried 2001 |
| Mountain big sagebrush | *Artemesia tridentata* *Bromus marginatus* | 0.43-1.10 | Idaho | point | Clark and Seyfried 2001 |
| Tallgrass prairie | *NA* | 3.2 | Kansas | NA | Lapitan and Parton 1996 |
| Grass steppe | *NA* | 0.5 | Colorado | light meter | Welles and Norman 1991 |

2.3.2 LAI Distribution

The annual LAI distribution function used in previous modeling at Tyrone was revised to incorporate the measured peak LAI values developed herein (Figure 2-2). Winter LAI remained near zero when plants are essentially dormant. The specified plant growth season begins in March when the average temperature climbs over 40°F. The abrupt increase in July corresponds to the typical arrival of the summer monsoons and associated thunderstorms. The growing period then extends into early October when the average temperatures begin to fall below 40°F.

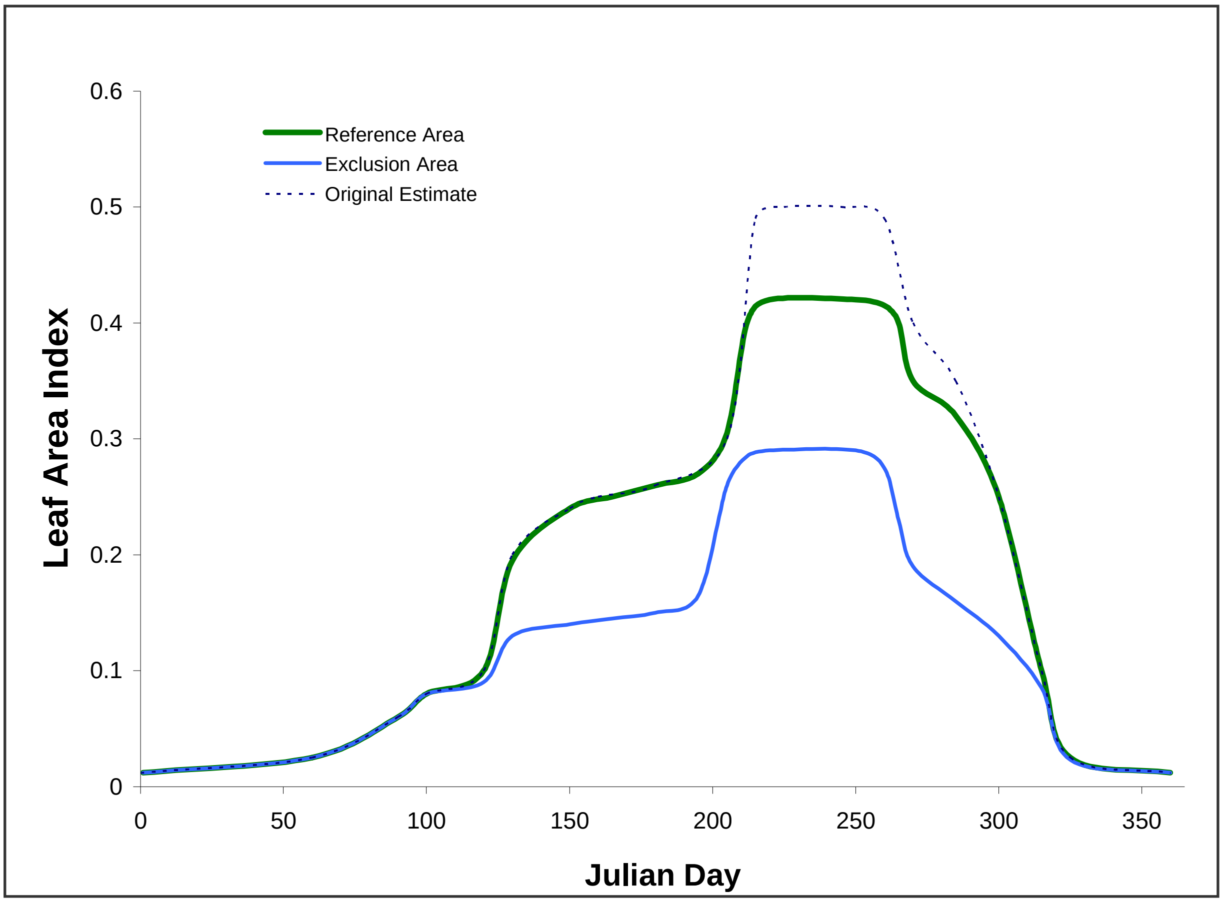



**Figure 2-2. Leaf Area Distribution Curves for Tyrone Mine.**

## 3.0 ROOT LENGTH DENSITY

Water is removed from the soil through the processes of evaporation and transpiration. Evaporation alone is relatively inefficient and can only remove water from comparatively shallow depths (2 to 3 feet) in well-drained soils. Transpiration increases the efficiency of water removal allowing more complete and deeper extraction of soil water. Because water movement by capillarity is limited in unsaturated soils, knowing the distribution of roots in the soil is important for predicting soil-water relations.

From a plant perspective, transpiration is passive with the energy supplied by the atmospheric demand created at the leaf surface. Plants roots constitute the interface between the soil, plant, and atmosphere. The atmospheric demand created at the leaf surface provides the energy needed to extract water. Water moves through the soil as a liquid and as vapor to root hairs, across into cells and up the xylem to stomatal openings on the leaf surface where it is evaporated. Negative pressures in the stem xylem may reach -20 bars at wilting point for agricultural crops, while desert plant may exist with potentials of -20 to -80 bars (Brady, 1974).

### 3.1 Methods

Root density was determined using the profile wall method, whereby the roots are counted to determine density (Moore and West, 1973, Böhm, 1979, Heitschmidt et al., 1988; Mackie-Dawson and Atkinson 1991; and Montaña et al., 1995). Trench locations were selected to represent grass/shrub plant communities, which are expected to be representative of the vegetation in the post-closure period. Three trenches were excavated in the piedmont scrub savanna plant community and two trenches were excavated in the revegetated plant communities in the South Main tailing repository (Fig. 2-1).

T-shaped trenches were excavated at all locations, except the hillside site (RS-1). After excavation, the soils were described by a Certified Professional Soil Scientist. The vertical pit wall was gently cleaned with a soft brush to expose the roots to a depth of about 1 to 1.5 meters. A 1 $m^2$ wire frame divided into a 10 $cm^2$ grid was then attached to the pit face and the roots within each grid cell were counted and classified by size (Fig. 3-1). The USDA system for describing roots was used to classify roots by size (Soil Survey Staff, 1983). The classes are: very fine (< 1 mm), fine (1 – 2 mm), medium (2 – 5 mm), coarse (5 – 10 mm), and very coarse (> 10 mm). The distribution of roots was mapped on field sheets. Roots counts were made on 13, 1-$m^2$ profiles at five separate sites. Three faces of the T-trench were evaluated at all sites, except the hillslope site where only one face was evaluated. Plant canopy cover within a foot (horizontal) of the trench was estimated. Generalized soil profile descriptions are included Appendix B.

**Figure 3-1. Root density sampling grid on the pit face at Site RS-1.**
Note: $CaCO_3$ accumulations (white masses) in the soil profile starting at 50 to 60 cm.

### 3.2 Results and Discussion

UNSAT-H applies a user-defined RLD function to allocate water removal from each node of the model domain (Fayer, 2000). For each node in the model domain, the transpiration demand is calculated as the fractional equivalent to the RLD of the node divided by the total root length in the profile. Accordingly, more water is extracted from zones with greater concentrations of roots. Thus, understanding the distribution of roots is important for validating the RLD function used in the soil-atmosphere model applied at Tyrone.

#### 3.2.1 Root Distribution

Characteristics of each of the root density study sites are listed in Table 3-1. In general, the soils were moderately deep to deep, well drained, and had moderately coarse textured surface horizons. The slopes were mostly nearly level to gently sloping, but one site was strongly sloping. Canopy cover ranged from 35 to 50 percent and vegetation immediately adjacent to the pit walls was dominantly grasses [i.e., blue grama (*Bouteloua gracilis*) and vine mesquite (*Hilaria belangeri*)] with scattered shrubs and forbs. As expected, the root densities are higher in the native soils compared to the repository sites (Table 3-1). The lower root density in the repositories soils when compared to the native sites is expected based on the lower leaf area measurements (Section 2).

**TABLE 3-1**
**TEST PIT SITE DESCRIPTIONS**

| Trench No. | Surface Texture | Soil Depth (cm) | Slope (percent) | Canopy Cover (percent) | Dominant Vegetation | Average Root Density (roots/m$^2$) |
|---|---|---|---|---|---|---|
| RS1- Native | Gr SL | 150 + | 31 | 40 | BOGR | 2,389 |
| RS2-Native | Gr SL | 125+ | 7 | 35 to 40 | BOGR-HIBE | 1,049 |
| RS3-Repository | Gr SL | 86 | 2 | 30 to 35 | BOGR | 1,009 |
| RS4-Repository | Gr SL | 100 | 1 | 25 to 50 | BOGR-ARSC | 714 |
| RS5-Native | Gr SL | 125+ | 9 | 25 to 35 | BOGR | 1,844 |

Notes: Gr SL gravelly sandy loam
BOGR = *Bouteloua gracilis*; HIBE = *Hilaria Belangeri*
ARSC = *Aristida schiedeana*

Regardless of sampling location (native or reclaimed), the roots were concentrated in the upper portions of the profile (Table 3-2). On average, 66 percent of the roots were in the upper 20 cm of the profile with more than 90 percent were in the upper 60 cm (2 feet). Figure 3-2 illustrates the average cumulative profile root distribution for both the native and reclaimed areas, and the average for the study area. Although they vary in magnitude, the shape of the curves are similar for both the native and reclaimed areas. The roots for both native and reclaimed areas were mostly very fine (< 1 mm); occasionally fine (1 to 2mm); and rarely medium and coarse (2 to 10 mm) reflecting the dominance of grasses. Data summaries for each sampling site are included in Appendix B.

**TABLE 3-2**
**SUMMARY OF ROOT DENSITY DATA FROM THE TYRONE STUDY AREA.**

| Depth Interval (cm) | Average Root Density (roots/dm$^2$) | | | Study Area Cumulative Average Root Density (percent) |
|---|---|---|---|---|
| | Native | Repository | Average | |
| 0 - 10 | 61.2 | 40.5 | 51.7 | 41 |
| 10 – 20 | 32.7 | 16.8 | 25.4 | 62 |
| 20 – 30 | 24.1 | 9.1 | 17.1 | 75 |
| 30 – 40 | 14.5 | 5.5 | 10.4 | 84 |
| 40 – 50 | 8.4 | 4.7 | 6.7 | 89 |
| 50 – 60 | 5.0 | 3.3 | 4.2 | 92 |
| 60 - 70 | 4.5 | 2.8 | 3.7 | 95 |
| 70 - 80 | 3.1 | 2.2 | 2.7 | 98 |
| 80 - 90 | 2.4 | 0.9 | 1.7 | 99 |
| 90 - 100 | 2.3 | 0.4 | 1.5 | 100 |

These data are consistent with the analysis of root distributions for terrestrial biomes throughout the world (Lee and Lauenroth, 1994; Moorhead et al., 1989; Rundel and Nobel, 1991; Schulze et al., 1996; and Sims and Singh, 1978). Jackson et al. (1996) reviewed 80 root studies to construct a database describing root density, cumulative root biomass, and cumulative root fraction. They indicated that the percentage of roots in the upper 30 cm of soil ranged from 83 percent in temperate grasslands to 53 percent in deserts.

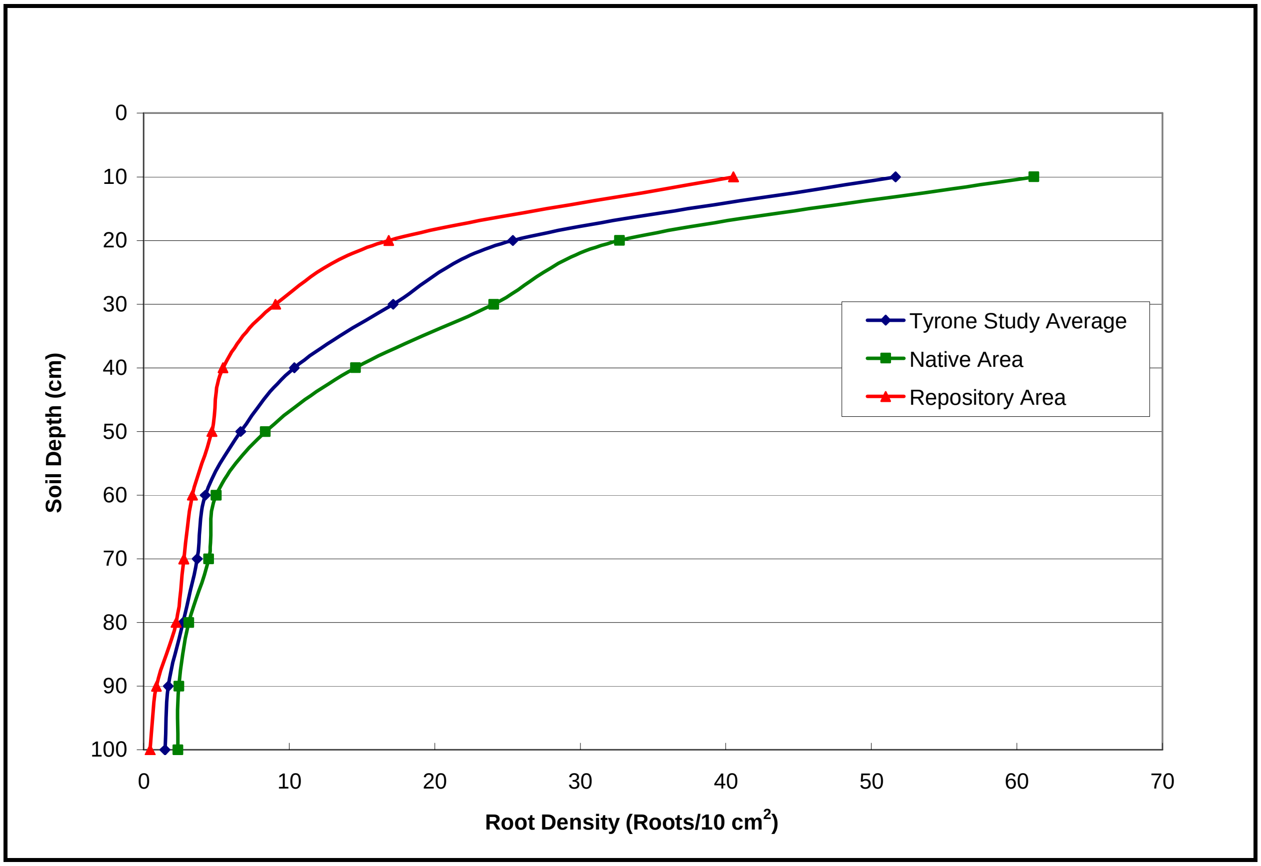



**Figure 3-2. Average cumulative root density profiles for the Tyrone study area.**

### 3.2.2 RLD Function

The RLD function used in previous modeling efforts at Tyrone was intended to emulate a 40-30-20-10 quartile root distribution, which is commonly assumed to occur in agricultural contexts (Ayers and Westcot, 1985; DBS&A, 1999a). In UNSAT-H, RLD is related to the depth below the surface (z) by the exponential equation:

$$RLD = ae^{-bz}+c$$

Where a, b, and c are coefficients that optimize the fit to normalized root density data (Fayer, 2000). The coefficients that best describe the average root density for the Tyrone study area are: a = 0.700, b = 0.060, c = 0.016. Table 3-3 lists RLD coefficients and root zone quartile functions for this and other studies. The coefficients determined for the 25th percentile (less roots in upper profile are: a = 0.700, b = 0.080, c = 0.007; and for the 75th percentile (more roots in upper profile) are: a = 0.910, b = 0.068, and c = 0.040.

**TABLE 3-3**
**RLD COEFFICIENTS AND ROOT ZONE QUARTILE FUNCTIONS FOR TYRONE AND OTHER AREAS**

| Study Reference | RLD Coefficients | | | Root Zone |
|---|---|---|---|---|
| | A | b | c | Quartile Function |
| DBS&A (1999a) | 0.250 | 0.030 | 0.001 | 40-30-20-10 |
| Tyrone Study (this report) | 0.700 | 0.060 | 0.016 | 69-20-7-4 |
| Sandia National Lab [a] | 0.509 | 0.063 | 0.026 | 63-24-11-2 |
| Temperate Grassland [b] | NA | NA | NA | 83-14-2-1 |
| Desert [b] | NA | NA | NA | 59-19-12-10 |
| Cheatgrass [c] | 1.163 | 0.129 | 0.020 | 85-10-4-1 |

Notes: a = from Peace et al. (2004)
b = from Jackson et al. (1996)
c = from Cline et al. (1977)

The root density curve for Tyrone is illustrated in Figure 3-3. For purposes of comparison, the RLD function used in previous modeling efforts at Tyrone (DBS&A, 1999a), and the curve developed at Sandia National Labs in Albuquerque (Peace et al., 2004) are also presented. The Tyrone and Sandia National Labs curves represent relatively higher proportions of the roots in the upper profile when compared to the function originally used for Tyrone. This result is expected since the original RLD function was estimated based on 40-30-20-10 root distribution commonly assumed for agricultural systems (Ayers and Westcot, 1985). Supply limitations associated with the prevailing climatic regime of the mid-elevations in New Mexico result in the concentration of roots in the upper part of the soil profile.

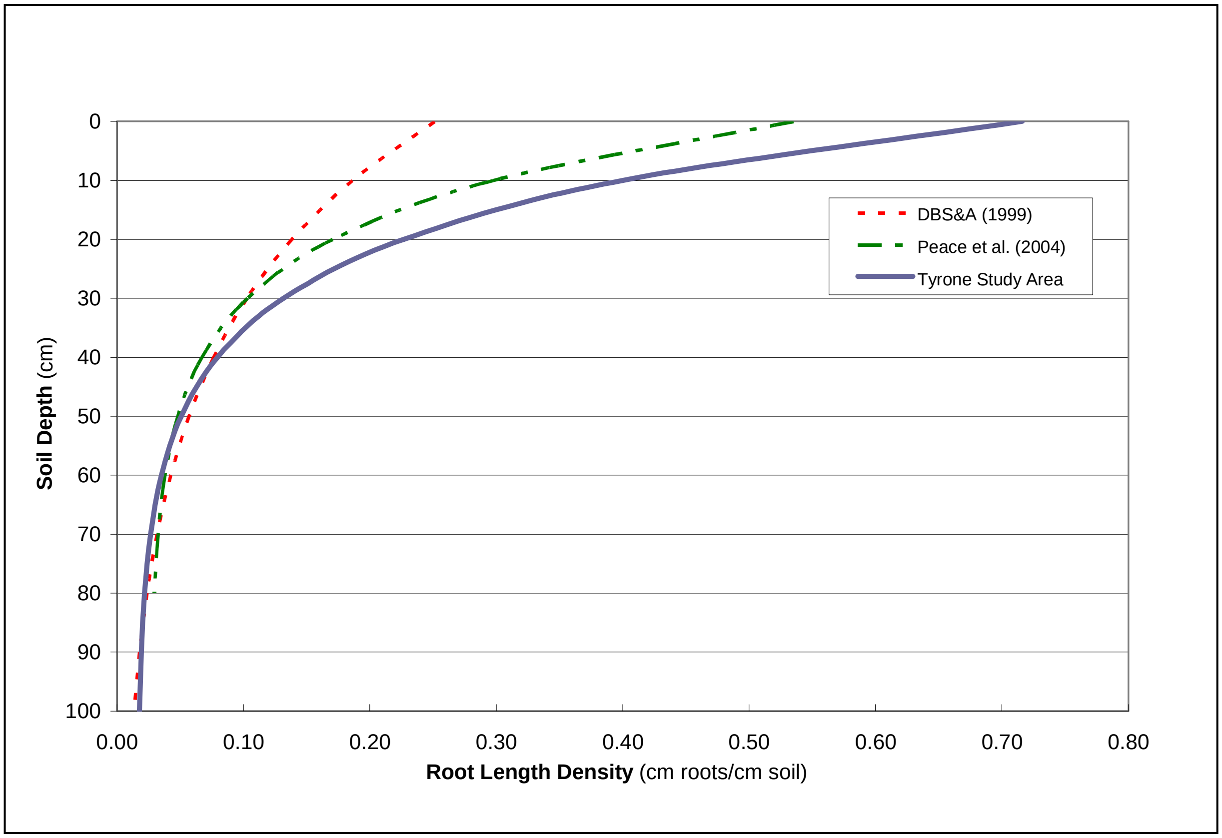



**Figure 3-3. Comparison of regional RLD functions and those used at Tyrone.**

## 4.0 COVER MATERIAL CHARACTERIZATION

Potential cover materials identified at Tyrone include native soils, recent alluvium, native Gila Conglomerate, Gila Conglomerate in the No. 1D stockpile, and leach cap oxide materials from the Little Rock Project and the Copper Mountain Pit expansion. The characteristics and suitability of these potential cover materials have been previously evaluated in the Borrow Materials Investigation (BMI) (DBS&A, 1997a), Soil and Rock Suitability Assessment (DBS&A, 1997b), Supplemental Materials Characterization study (DBS&A, 1997b), and Little Rock Mine Cover Design Report and Test Plot Work Plan (Golder, 2004). Table 4-1 summarizes the kind and number of samples and the types of analyses conducted for past closure studies. The soil analyses were conducted using standard methods which are consistent with the 1996 MMD Draft Closeout Plan Guidelines (MMD, 1996).

**TABLE 4-1**
**EXISTING DATA FOR GILA CONGLOMERATE AND LEACHED CAP MATERIAL AT TYRONE MINE.**

| Material/Report | No. of Samples | Analytical Data |
|---|---|---|
| **Gila Conglomerate** | | |
| CCP, Soil and Rock Suitability, Appendix C (DBS&A, 1997c) | 14 | paste pH, EC, major cations, SAR, Se, B, $CaCO_3$, saturation percent, particle size, rock fragments, ABA, Atterberg Limits, Standard Proctor Compaction Test |
| Cover Design Status Report (DBS&A, 1999a) | 11 | particle size, rock fragments, $K_{sat}$, volumetric water content, available water capacity, unsaturated hydraulic properties |
| PMC (DBS&A, 1997a) | 6 | ABA, paste pH, whole rock metal analyses (11 metals), SPLP Extract (2 samples), X-ray diffraction including clay mineralogy (3 samples) |
| **Leached Cap Materials** | | |
| Copper Mountain Stockpile Reclamation (PDTI, 2002) | 7 | paste pH, EC, saturation percent, particle size, rock fragments, phosphorous, nitrate |
| PMC (DBS&A, 1997a) | 9 | ABA, paste pH, whole rock metal analyses (11 metals), SPLP Extract (1 sample), Petrographic analysis (2 samples), X-ray diffraction (2 samples) |
| SMC (DBS&A, 1997b) | 10 | ABA, paste pH, whole rock metal analyses (20 metals), SPLP Extract (2 samples), X-ray diffraction (2 samples) |
| Little Rock Cover Design Report and Test Plot Work Plan (Golder, 2004) | 15 | paste pH, EC, saturation percent, particle size, rock fragments, phosphorous, nitrate |

The soils that will be used to cover the stockpiles and tailing impoundments will be excavated from numerous locations on the mine property. Additional materials characterization is planned as part of the test plot program and the Supplemental Borrow Materials Investigation as required in Conditions 76 and 79 (DP-1341) and the MMD permit. Volumetric estimates of available materials will be developed as part of Condition 79. The intent of this section is to compile the existing data and summarize the characteristics of these materials. Chemical and physical properties are discussed in Section 4.1 and soil hydraulic properties in Section 4.2.

## 4.1 Chemical and Physical Properties

The chemical and physical properties of the Gila Conglomerate and associated soils, and the leached cap materials are discussed in this section. The data from the existing studies are compiled in Appendix C. The Gila Conglomerate and associated soils are discussed in Section 4.1.1 and leach cap materials are discussed in Section 4.1.2.

### 4.1.1 Gila Conglomerate and Associated Soils

Detailed soil surveys conducted in and around the Tyrone Mine indicated that significant volumes of primary and secondary root zone materials exist at Tyrone. The primary root zone materials have few or no inherent limitations for supporting native and adapted plant species. From a plant growth and erosion protection perspective, the best available materials for cover construction are moderately coarse- to medium-textured soils with moderate rock fragment contents.

Physically, the fine-earth fraction (i.e., < 2mm) of the Gila Conglomerate and associated soils are dominantly moderately coarse-textured and mainly represented by loamy sand and sandy loam textures (Appendix C). Fine-, moderately fine-, and coarse-textured soils occur locally. In general, the coarse-textured soils are more prevalent in and around the mine area, and the finer textured soils tend to occur on the flanks of the Little Burro Mountains east of the tailing ponds. The soils around Tyrone typically contain about 30 to 50 percent rock fragments (> 2 mm diameter) by volume, generally ranging from 0 to 75 percent. Saturation percentages for the soils generally range from 18 to 75 percent and are well correlated with clay content, suggesting a fairly consistent mineralogical regime (Figure 4-1).

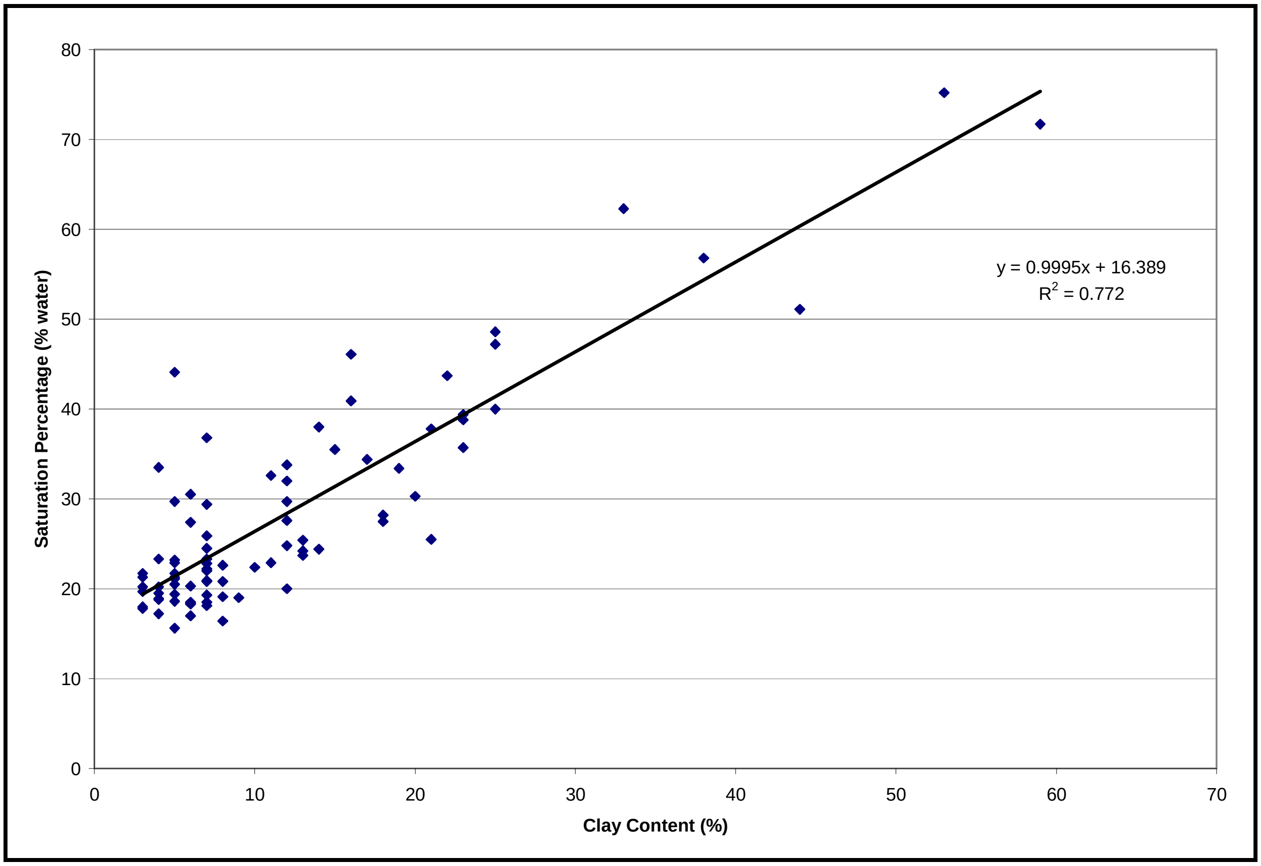



**Figure 4-1. Correlation of clay content and saturation percentage for soils at Tyrone.**

Chemically, the Gila Conglomerate and associated soils have few inherent limitations. The pH of the soils range from about 5.0 to 7.8 and the salinity levels are low (0.2 to 3.8 ds/m). These materials are universally nonsodic and have favorable calcium to magnesium ratios. The soluble selenium and boron levels are low. The materials range from noncalcareous to calcareous and contain 0.5 to 9.2 percent $CaCO_3$ equivalent. The highest levels of $CaCO_3$ are found in the subsurface of the soils in the Mangas Valley. Additional testing of the Gila Conglomerate on the 5A stockpile is planned as part of the supplemental materials characterization study (Condition 79) and will be incorporated into the database as soon as they become available.

### 4.1.2 Leached Cap Materials

Leached cap materials may be used as cover in some portions of the mine. Leached cap is overburden that is available at the Little Rock Mine and Copper Mountain Pit expansion areas and consists predominantly of materials classified as Mineral Assemblage 1 (MA-1) at the mine. Overall, it is a net-neutralizing material that is non-acid-generating (DBS&A, 1997a). Results from the Supplemental Materials Characterization (SMC) indicate that MA-1 exhibits ABA's that are evenly distributed around a neutral ABA (DBS&A, 1997b). For instance, 10 of the 19 MA-1 samples collected as part of the SMC were positive and 9 were negative, with values ranging between +23.7 and –38.8 tons $CaCO_3$ per 1,000 tons rock (average ABA –1.51 t/kt). Paste pH values of these materials ranged from 5.0 to 8.4, with an average of approximately 6.9 (DBS&A, 1997b).

ABA analyses were also performed on pulp samples from four exploration drill holes in the Copper Mountain pit expansion area and on representative samples of the mined material as part of the Plan of Operation for the Copper Mountain Mine Expansion Project (PDTI, 2003). All of the oxide material (MA-1) types that were analyzed showed a strong net acid neutralizing potential (ANP) with a ratio of ANP to AGP of well over 3, except for one sample, which did not have any measurable acid-generating potential. ABA values ranged from zero (a sample with no AGP or ANP detected) to 46.7 t/kt and tended to become more positive with depth. These results suggest that these materials are strongly net-neutralizing and may be used as cover. Summary data for these materials are provided in Appendix C

Laboratory analyses indicate that the overburden at Little Rock is relatively uniform in nature (Appendix C) and has few apparent limitations as a plant growth media when compared to the native soils. Chemically, the overburden does not vary significantly and is comparable to the native soils. There are no apparent chemical limitations with respect to salinity in either the overburden or the native soils and the pH and extractable nitrate concentrations occur at similar levels in both materials. The overburden is moderately coarse-textured (e.g., sandy loams) and contains moderate volumes of rock fragments. The native soils exhibited similar characteristics and are moderately coarse-textured with moderate amounts of rock fragments (PDTI, 2000). Thus, the overburden at the Little Rock Mine is considered to be a reasonable soil substitute relative to the native soils in the permit area.

## 4.2 Soil Hydraulic Properties

Infiltration, redistribution, and drainage of water are dependant on soil hydraulic properties, which UNSAT-H describes using mathematical functions. Key input parameters include saturated hydraulic conductivity ($K_{sat}$), van Genuchten coefficients, and water characteristic functions. The hydraulic properties analyzed for and the associated studies test methods are presented in Table 4-2. The van Genutchen coefficients, used to relate wetness to matric suction and hydraulic conductivity, were developed using measured data and the RETC model (van Genutchen et al., 1991). The residual water content ($\theta_r$) and saturated water content ($\theta_s$) are empirical constants. Residual water is defined as the water that will not contribute to liquid flow either because of strong adsorption or the pores are unconnected. Saturated water represents the maximum water content in the field.

### 4.2.1 Soil-Moisture Retention Characteristics

Soil-moisture retention characteristic curves were developed through a combination of hanging-column tests and pressure plate tests. The results of these analyses are included in Appendix C and summarized in Table 4-3. These data are presented as moisture contents at various suctions, beginning at a suction of 0 bars (saturated moisture content) and continuing through to a suction of 15 bars. The saturated moisture content of the < 2 mm soil fraction samples ranged between 0.34 and 0.6 $cm^3/cm^3$, with an average of approximately 0.43 $cm^3/cm^3$. The saturated moisture content of the bulk samples (including the rock fragments) were also estimated using the methods developed by Dunn and Mehuys (1984) and Bouwer and Rice (1984). These results show the saturated moisture content of the bulk samples ranged from 0.13 to 0.59 $cm^3/cm^3$, with an average of about 0.28 $cm^3/cm^3$. The 15-bar moisture content of the < 2 mm soil fraction samples ranged between 0.03 and 0.22 $cm^3/cm^3$, with an average of approximately 0.11 $cm^3/cm^3$. The estimated 15-bar moisture content of the bulk samples ranged from 0.02 to 0.15 $cm^3/cm^3$, with an average of about 0.07 $cm^3/cm^3$.

**TABLE 4-2**
**SOIL-HYDRAULIC CHARACTERIZATION METHODS**

| Analysis | Method |
|---|---|
| Saturated hydraulic conductivity ($K_{sat}$) | ASTM 2434-68 |
| Moisture retention curves (6 to 9 points) | ASTM D 2325-68 (94) |
| Antecedent water content | Gardner (1986) |
| Van Genuchten parameters (RETC4) | van Genuchten et al., (1991) |
| Rock fragment content | ASTM D 2487-90 |
| Particle density | Blake and Hartge (1986) |

Based on the test data, soil-moisture characteristic curves were developed and the residual moisture contents and unsaturated hydraulic conductivity ($K_{unsat}$) relationships ($K_{unsat}$ verses moisture content and $K_{unsat}$ versus suction) of the individual samples were estimated using the methods of van Genuchten (1978; 1980). The calculated van Genuchten parameters ($\alpha$ and N) for the individual samples are also presented in Table 4-3.

### 4.2.2 Saturated Hydraulic Conductivity

The saturated hydraulic conductivity ($K_{sat}$) of the <2 mm soil fraction samples was determined by either the constant-head or falling-head method, depending on the clay fraction of the sample being tested. The calculated $K_{sat}$ of the samples ranges from 1.3 x $10^{-5}$ to 5.90 x $10^{-2}$ cm/s (Table 4-4),

**TABLE 4-3**
**SOIL HYDRAULIC PROPERTIES FOR TYRONE SOILS**
**AND GILA CONGLOMERATE (ADAPTED FROM DBS&A, 1997C).**

| Sample Name | Type [a] | Particle Size (%) | | | USDA Class[b] | Rock Fragments (Vol %) | Saturated Hydraulic Conductivity (cm/s) | | Volumetric Water Content[c] ($cm^3/cm^3$) | | | | | | | | | | van Genuchen Coefficients | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | $\Theta_r$ | | $\Theta_s$ | | $\Theta_{1/3}$ | | $\Theta_{15}$ | | AWC | | a | N |
| | | Sand | Silt | Clay | | | <2mm | Whole Soil | <2mm | Corrected | <2mm | Corrected | <2mm | Corrected | <2mm | Corrected | <2mm | Corrected | 1/cm | dimensionless |
| 1D-1 | GC | 87 | 10 | 3 | S | 67 | 7.30 E-3 | 1.80 E-3 | 0.03 | 0.01 | 0.43 | 0.1419 | 0.17 | 0.056 | 0.07 | 0.023 | 0.7 | 0.231 | 0.113 | 1.2048 |
| 1D-5 | GC | 84 | 11 | 5 | LS | 67 | 5.90 E-2 | 1.46 E-2 | 0 | 0 | 0.53 | 0.1749 | 0.16 | 0.053 | 0.07 | 0.023 | 0.5 | 0.165 | 0.0336 | 1.2993 |
| TP-1 0-2.5 | Alluv | 26 | 54 | 20 | SiL | 10 | 3.30 E-5 | 2.83 E-5 | 0 | 0 | 0.45 | 0.4050 | 0.34 | 0.306 | 0.17 | 0.153 | 0.07 | 0.063 | 0.0316 | 1.448 |
| TP-2 4-13 | Alluv | 71 | 22 | 7 | SL | 10 | 5.50 E-4 | 4.71 E-4 | 0.03 | 0.027 | 0.41 | 0.3690 | 0.22 | 0.198 | 0.1 | 0.090 | 0.11 | 0.099 | 0.0295 | 1.2856 |
| TP-3 1-9 | Alluv | 77 | 16 | 7 | LS | 10 | 6.90 E-3 | 5.91 E-3 | 0.05 | 0.0450 | 0.45 | 0.4050 | 0.2 | 0.180 | 0.08 | 0.072 | 0.1 | 0.090 | 0.0191 | 1.3129 |
| TP-3 9-14 | Alluv | 49 | 39 | 12 | L | 50 | 2.90 E-4 | 1.16 E-4 | 0.03 | 0.015 | 0.49 | 0.2450 | 0.27 | 0.135 | 0.11 | 0.055 | 0.15 | 0.075 | 0.0054 | 1.1698 |
| TP-4 2.5-14 | Alluv | 48 | 45 | 7 | L | 55 | 1.60 E-4 | 5.65 E-5 | 0.03 | 0.014 | 0.34 | 0.1530 | 0.21 | 0.095 | 0.08 | 0.036 | 0.1 | 0.045 | 0.0689 | 1.1933 |
| TP-8 0.1-4.95 | GC | 37 | 33 | 30 | CL | 37 | 1.50 E-5 | 7.97 E-6 | 0 | 0 | 0.46 | 0.2898 | 0.4 | 0.252 | 0.22 | 0.139 | 0.17 | 0.107 | 0.2807 | 1.1958 |
| TP-8 4-12 | GC | 72 | 21 | 7 | SL | 65 | 4.20 E-4 | 1.11 E-4 | 0 | 0 | 0.51 | 0.1785 | 0.29 | 0.102 | 0.14 | 0.049 | 0.12 | 0.042 | 0.0612 | 1.3618 |
| TP-9 4-8 | GC | 60.1 | 15 | 25 | SCL | 2 | 2.70 E-3 | 2.62 E-3 | 0 | 0 | 0.6 | 0.5880 | 0.25 | 0.245 | 0.12 | 0.118 | 0.1 | 0.098 | 0.0226 | 1.2159 |
| TP-10 2-8 | GC | 54 | 28 | 18 | SL | 25 | 1.00 E-3 | 6.67 E-4 | 0.04 | 0.030 | 0.46 | 0.3450 | 0.19 | 0.143 | 0.08 | 0.060 | 0.1 | 0.075 | 0.0307 | 1.1721 |
| TP-10 8-18 | GC | 52 | 35 | 13 | L | 15 | 1.30 E-5 | 1.03 E-5 | 0 | 0 | 0.39 | 0.3315 | 0.25 | 0.213 | 0.12 | 0.102 | 0.12 | 0.102 | 0.0267 | 1.2944 |
| TP-11 4-16 | GC | 57 | 20 | 23 | SCL | 60 | 2.50 E-5 | 7.69 E-6 | 0 | 0 | 0.43 | 0.1720 | 0.29 | 0.116 | 0.15 | 0.060 | 0.13 | 0.052 | 0.3936 | 1.3008 |
| TP-13 2.5-6 | Alluv | 88 | 8 | 4 | S | 60 | 5.70 E-3 | 1.75 E-3 | 0 | 0 | 0.38 | 0.1520 | 0.2 | 0.080 | 0.07 | 0.028 | 0.5 | 0.200 | 0.0929 | 1.2003 |
| TP-13 6-14 | Alluv | 94 | 3 | 3 | S | 0 | 4.00 E-3 | 4.00 E-3 | 0 | 0 | 0.37 | 0.3700 | 0.09 | 0.090 | 0.03 | 0.030 | 0.1 | 0.100 | 0.073 | 1.2983 |
| TP-14 0-20 | GC | 65.1 | 18 | 17 | SL | 30 | 5.10 E-4 | 3.10 E-4 | 0 | 0 | 0.46 | 0.3220 | 0.24 | 0.168 | 0.11 | 0.077 | 0.11 | 0.077 | 0.0384 | 1.1627 |
| TP-17 2-20 | GC | 76 | 13 | 11 | SL | 13 | 4.70 E-4 | 3.84 E-4 | 0.02 | 0.0174 | 0.34 | 0.2958 | 0.15 | 0.131 | 0.06 | 0.052 | 0.7 | 0.609 | 0.0309 | 1.2169 |
| TP-18 2-5 | GC | 72 | 7 | 21 | SCL | 40 | 1.00 E-4 | 5.00 E-5 | 0 | 0 | 0.41 | 0.2460 | 0.27 | 0.162 | 0.16 | 0.096 | 0.1 | 0.060 | 0.0271 | 1.2382 |
| TP-19 2-11 | Alluv | 66 | 22 | 12 | SL | 5 | 4.90 E-4 | 4.54 E-4 | 0 | 0 | 0.37 | 0.3515 | 0.23 | 0.219 | 0.1 | 0.095 | 0.11 | 0.105 | 0.0638 | 1.3356 |
| TP-21 5-14 | Alluv | 52 | 42 | 6 | SL | 67 | 1.70 E-3 | 4.20 E-4 | 0 | 0 | 0.39 | 0.1287 | 0.24 | 0.079 | 0.1 | 0.033 | 0.13 | 0.043 | 1.0855 | 1.213 |

[a] GC = Gila Conglomerate
Alluv = Alluvium
[b] USDA texture class according to Soil Survey Division Staff (1993)
[c] $\Theta_r$ = residual moisture content
$\Theta_s$ = saturated moisture content
$\Theta_{1/3}$ = 1/3 bar moisture content
$\Theta_{15}$ = 15 bar moisture content
Corrected = corrected for gravel content
AWC = available water-holding capacity

with a geometric mean of approximately 5.5 x $10^{-4}$ cm/s and a standard deviation of 0.013cm/s. The $K_{sat}$ of the bulk samples (including the rock fragments) were also estimated using the methods developed by Dunn and Mehuys (1984) and Bouwer and Rice (1984). These results show the saturated hydraulic conductivities of the bulk samples ranging between 7.69 x $10^{-6}$ cm/s to 1.46 x $10^{-2}$ cm/s, with a geometric mean of approximately 2.9 x $10^{-4}$ cm/s and a standard deviation of 0.003 cm/s. The $K_{sat}$ values obtained from the individual samples are consistent with published values for these material types (loamy sands and sandy loams) (Freeze and Cherry, 1979).

**TABLE 4-4.**
**CALCULATED AND PREDICTED HYDRAULIC PROPERTIES FOR TYRONE SOILS AND GILA CONGLOMERATE (ADAPTED FROM DBS&A, 1997C)**

| Sample Name | Type [a] | Particle Size (%) | | | USDA Class [b] | Saturated Hydraulic Conductivity (cm/s) | | Volumetric Water Content ($cm^3/cm^3$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | $\Theta_s$ | | $\Theta_{1/3}$ | | $\Theta_{15}$ | | AWC | |
| | | Sand | Silt | Clay | | Calc. | Predict | Calc. | Predict | Calc. | Predict | Calc. | Predict | Calc. | Predict |
| 1D-1 | GC | 87 | 10 | 3 | S | 7.3 E-3 | 1.9 E-3 | 0.43 | 0.352 | 0.17 | 0.136 | 0.07 | 0.058 | 0.7 | 0.08 |
| 1D-5 | GC | 84 | 11 | 5 | LS | 5.9 E-2 | 1.7 E-2 | 0.53 | 0.354 | 0.16 | 0.141 | 0.07 | 0.060 | 0.5 | 0.08 |
| TP-1 0-2.5 | Alluv | 26 | 54 | 20 | SiL | 3.3 E-5 | 2.4 E-4 | 0.45 | 0.475 | 0.34 | 0.282 | 0.17 | 0.122 | 0.07 | 0.16 |
| TP-2 4-13 | Alluv | 71 | 22 | 7 | SL | 5.5 E-4 | 1.1 E-3 | 0.41 | 0.383 | 0.22 | 0.173 | 0.1 | 0.075 | 0.11 | 0.10 |
| TP-3 1-9 | Alluv | 77 | 16 | 7 | LS | 6.9 E-3 | 1.1 E-3 | 0.45 | 0.379 | 0.2 | 0.165 | 0.08 | 0.072 | 0.1 | 0.09 |
| TP-3 9-14 | Alluv | 49 | 39 | 12 | L | 2.9 E-4 | 5.0 E-4 | 0.49 | 0.429 | 0.27 | 0.227 | 0.11 | 0.097 | 0.15 | 0.13 |
| TP-4 2.5-14 | Alluv | 48 | 45 | 7 | L | 1.6 E-4 | 8.9 E-4 | 0.34 | 0.400 | 0.21 | 0.227 | 0.08 | 0.084 | 0.1 | 0.14 |
| TP-8 0.1-4.95 | GC | 37 | 33 | 30 | CL | 1.5 E-5 | 8.6 E-5 | 0.46 | 0.490 | 0.4 | 0.300 | 0.22 | 0.169 | 0.17 | 0.13 |
| TP-8 4-12 | GC | 72 | 21 | 7 | SL | 4.2 E-4 | 1.1 E-3 | 0.51 | 0.382 | 0.29 | 0.172 | 0.14 | 0.074 | 0.12 | 0.10 |
| TP-9 4-8 | GC | 60.1 | 15 | 25 | SCL | 2.7 E-3 | 1.0 E-4 | 0.6 | 0.463 | 0.25 | 0.244 | 0.12 | 0.150 | 0.1 | 0.10 |
| TP-10 2-8 | GC | 54 | 28 | 18 | SL | 1.0 E-3 | 2.3 E-4 | 0.46 | 0.449 | 0.19 | 0.232 | 0.08 | 0.119 | 0.1 | 0.11 |
| TP-10 8-18 | GC | 52 | 35 | 13 | L | 1.3 E-5 | 4.3 E-4 | 0.39 | 0.432 | 0.25 | 0.224 | 0.12 | 0.100 | 0.12 | 0.12 |
| TP-11 4-16 | GC | 57 | 20 | 23 | SCL | 2.5 E-5 | 1.3 E-4 | 0.43 | 0.460 | 0.29 | 0.243 | 0.15 | 0.141 | 0.13 | 0.10 |
| TP-13 2.5-6 | Alluv | 88 | 8 | 4 | S | 5.7 E-3 | 1.9 E-3 | 0.38 | 0.352 | 0.2 | 0.133 | 0.07 | 0.058 | 0.5 | 0.07 |
| TP-13 6-14 | Alluv | 94 | 3 | 3 | S | 4.0 E-3 | 2.2 E-3 | 0.37 | 0.347 | 0.09 | 0.122 | 0.03 | 0.055 | 0.1 | 0.07 |
| TP-14 0-20 | GC | 65.1 | 18 | 17 | SL | 5.1 E-4 | 2.5 E-4 | 0.46 | 0.437 | 0.24 | 0.214 | 0.11 | 0.117 | 0.11 | 0.10 |
| TP-17 2-20 | GC | 76 | 13 | 11 | SL | 4.7 E-4 | 5.9 E-4 | 0.34 | 0.405 | 0.15 | 0.177 | 0.06 | 0.091 | 0.7 | 0.09 |
| TP-18 2-5 | GC | 72 | 7 | 21 | SCL | 1.0 E-4 | 1.4 E-4 | 0.41 | 0.444 | 0.27 | 0.218 | 0.16 | 0.135 | 0.1 | 0.08 |
| TP-19 2-11 | Alluv | 66 | 22 | 12 | SL | 4.9 E-4 | 4.9 E-4 | 0.37 | 0.417 | 0.23 | 0.195 | 0.1 | 0.096 | 0.11 | 0.10 |
| TP-21 5-14 | Alluv | 52 | 42 | 6 | SL | 1.7 E-3 | 1.0 E-3 | 0.39 | 0.388 | 0.24 | 0.218 | 0.1 | 0.079 | 0.13 | 0.14 |

Notes:
Analysis completed on the <2mm fraction
"Compaction" held constant at normal
Calculations completed using the methodology of Saxton et al. (1985)
[a] GC = Gila Conglomerate, Alluv = Alluvium
[b] USDA texture class according to Soil Survey Division Staff (1993)

## 5.0 LONG-TERM SOIL WATER BALANCE SIMULATIONS

Long-term average drainage below the proposed covers at PDTI was evaluated using the UNSAT-H model (Fayer, 2000). Developed by Battelle Pacific Northwest Laboratory, UNSAT-H is a one-dimensional soil water and heat flux model that simulates the dynamic processes of infiltration, drainage, redistribution, evaporation, and transpiration. UNSAT-H uses a fully implicit, finite difference method for solving the water and heat flow equations. Mathematically, the model uses Richards' equation for water flow, Fick's law for vapor diffusion, and Fourier's law for heat flow. The model is particularly effective in evaluating the effects of changes in hydraulic conductivity under transient soil water conditions.

UNSAT-H uses edaphic, meteorological, and vegetation input data to simulate fluxes of moisture and energy. Specifically, the required soil material inputs include bulk density, porosity, several water characteristic functions, saturated hydraulic conductivity, and relative hydraulic conductivity functions. Daily weather conditions (precipitation, temperature, relative humidity, wind speed, cloud cover, and solar radiation) constitute the climatic data input requirements. Plant input parameters include leaf area index, percentage of bare area, growing season, suction head limits, and a RLD function. Choices for the lower boundary condition in the model can be controlled as either head constant (i.e. constant matric potential or temperature) or a head-dependent flux (e.g., water fluxes and temperature gradient).

Three covers depths were evaluated using UNSAT-H for the waste rock piles and leach ore stockpiles (60, 90, and 120 cm) and four cover depths (45, 60, 90, and 120 cm) were evaluated for the tailing impoundments to compare long-term drainage. The model domain was constructed to include stockpile or tailing material below the soil cover and contained approximately 40 to 50 nodal points. The bottom boundary was located 10 m below the base of the cover; a point beyond any influence from the cover layer, and was specified as a unit gradient or free-draining boundary. The unit gradient boundary condition is used when there is a thick unsaturated zone between the base of the cover and the underlying water table (McCord 1991). Assuming a unit gradient as the lower boundary condition, any water that moves to the base of the model domain will drain freely out of the system.

These simulations also incorporated the revisions to the input parameters developed in previous sections (i.e., cover hydrologic data, LAI, and RLD). Drainage was assessed at the node corresponding to the 182 cm (6 foot) depth. Sensitivity analyses were also conducted on the 60 cm covers by varying the peak leaf area. The UNSAT-H input parameters and annual summary data are included Appendix D. UNSAT-H output files are included on the compact disk that accompanies this document.

## 5.1 Climate Data

Upper boundary conditions were developed using measured daily weather data, where possible. Precipitation, temperature, wind speed, and other climatic data needed to support the soil-hydrologic modeling were derived from a variety of sources. Based upon review of the available data, the 100-year daily precipitation and temperature record from Ft. Bayard weather station (National Climatic Data Center [NCDC] Cooperative Weather Station #293265) is the most complete and longest record for the Silver City area and was used for this evaluation (Figure 5-1).

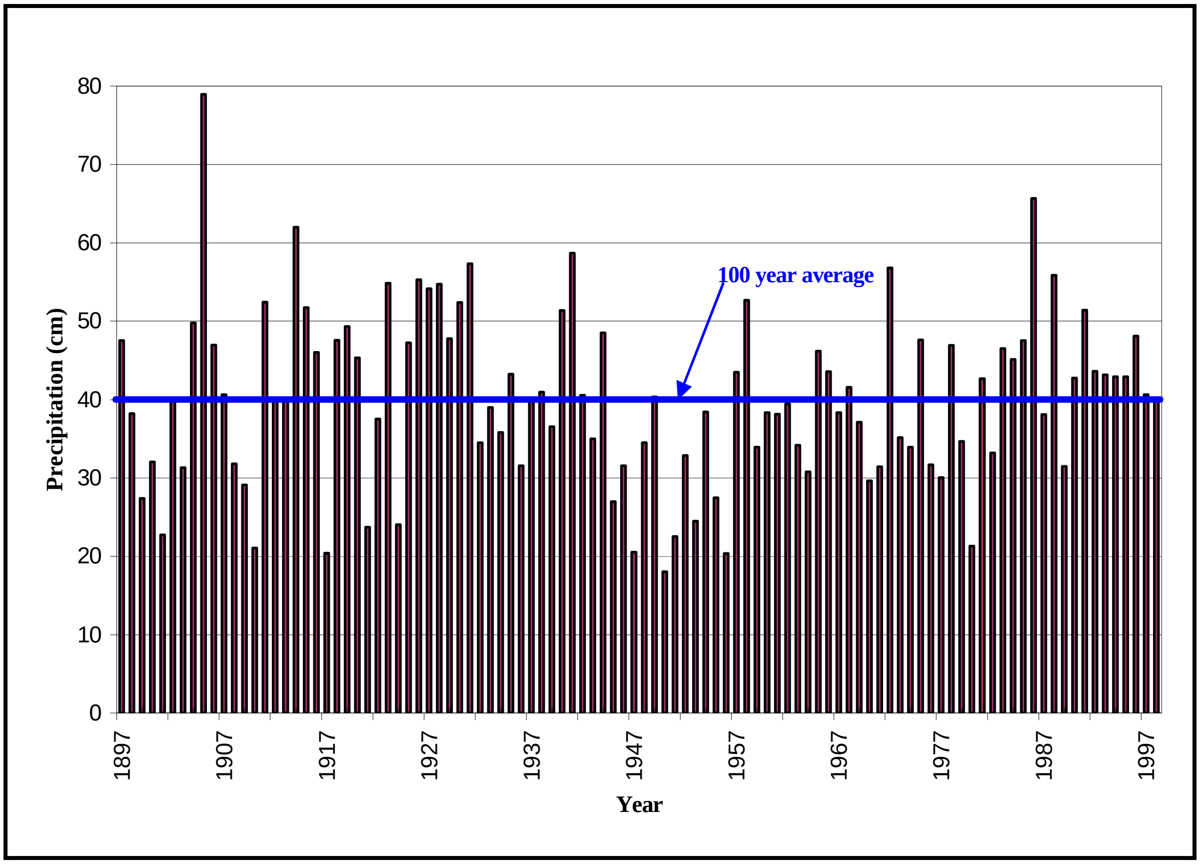



**Figure 5-1. Precipitation 1897-1999, Fort Bayard, New Mexico**

Average monthly wind speed data from the NCDC weather station at Deming (Cooperative Weather Station #292436) was used for the evaluation. Cloud cover and relative humidity were taken from monthly averages recorded in Albuquerque (NCDC, accessed in 1999) and dew point was calculated from the relative humidity data. Solar radiation was calculated from published relationships based on latitude (Barbour et al. 1987). Climatically, the simulation record represents a broad range of conditions typical of the region including wet winters and summers, and prolonged droughts and wet intervals.

### 5.2 Vegetation Data

To maintain conservatism in the water balance model, the peak annual LAI used in CCPE simulations was 0.29, equivalent to the average value measured for the reclaimed tailing repository (Section 2.3). The LAI distribution ranged from nearly 0 during the dormant period (winter) to a peak of 0.29 during the growing season (Figure 2-2). To determine the effects on the model results, the two additional simulations for 60 cm cover on the tailing and stockpile to the reference area value of 0.42 (Section 2.3).

The site-specific RLD parameters described in Section 3.0 were used in the CCPE simulations. In all simulations, roots were restricted to the cover domain. Critical suction head limits were selected for wilting point, decreased transpiration, and anaerobic conditions. Wilting point is the soil-water content at the soil-water potential where a particular plant species either wilts or becomes dormant (Ritchie, 1981). Wilting point is typically about 15 bars for crop plants; 25 to 30 for prairie grasses; and may exceed 60 bars for some desert shrubs. The critical suction-head limits selected for the model include 20,000 cm (20 bars) for wilting point, 3,000 cm (3 bars) for the point at which plant transpiration decreases (Gardner, 1983), and 1 cm (0.001 bar) as the point where transpiration stops due the imposition of anaerobic conditions. Additional vegetation parameters for the water balance model are provided in Appendix D.

### 5.3 Soil Hydraulic Properties

Infiltration, redistribution, and drainage of water are dependant on soil hydraulic properties, which UNSAT-H using mathematical functions. Key input parameters include saturated hydraulic conductivity ($K_{sat}$), van Genuchten coefficients, and water-characteristic functions.

The soil hydraulic properties necessary to perform the CCPE were estimated using similar materials tested at the Tyrone Mine (DBS&A, 1999a). Based on similarities of the fine earth fraction of the Gila Conglomerate, sample TP-3 1-9' (loamy sand; < 2mm $K_{sat}$ = 6.9 x $10^{-3}$ cm/s) was selected to represent cover materials for Tyrone. Soil hydraulic properties were modified to account for somewhat higher average rock volume observed in the Gila Conglomerate. Input soil hydrologic parameters are consistent with published, standardized relationship among soil particle size and hydraulic properties of similarly textured soils (Rawls et al., 1982; Carsel and Parrish, 1988). Additional soil hydraulic properties of TP-3 1-9' are given in Appendix D. Thus, this analysis provides a conservative estimate of long-term drainage with the conditions that occur in the field.

### 5.4 Simulation Results

The UNSAT-H model was used to evaluate the performance of different cover soil profiles using the site-specific input parameters and cover materials identified for the reclamation at Tyrone. The simulation results for the cover thickness scenarios for stockpiles and tailings are presented in Table 5-1. Average annual drainage for the 100-year simulation period was less than 1 percent of mean annual precipitation (MAP; 400 mm) for all cover scenarios. Runoff, an important component of the water balance, was estimated to be less than 1 percent MAP for all simulations. This suggests that a 60 cm cover composed of similarly textured Gila Conglomerate could meet the goal of limiting average drainage to less than 1 percent MAP. Annual summaries for all simulations are provided in Appendix D.

**TABLE 5-1**
**SIMULATED DRAINAGE AND RUNOFF OF VARIOUS COVER DEPTHS FOR TYRONE STOCKPILES AND TAILING**

| | Stockpile Cover Depth (cm) | | | | | Tailing Cover Depth (cm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 60 | 60HL[a] | 90 | 120 | | 45 | 60 | 60HL[a] | 90 | 120 |
| Drainage (mm) | 3.5 | 2.9 | 1.8 | 2.9 | | 0.4 | 2.6 | 1.9 | 1.0 | 0.4 |
| percent MAP[b] | 0.87% | 0.72% | 0.45% | 0.72% | | 0.92% | 0.64% | 0.47% | 0.24% | 0.11% |
| Runoff (mm) | 0.2 | 0.2 | 0.2 | 0.2 | | 0.01 | 0.2 | 0.5 | 0.2 | 0.2 |
| percent MAP[b] | 0.06% | 0.06% | 0.05% | 0.05% | | 0.03% | 0.06% | 0.12% | 0.05% | 0.05% |

[a] HL = maximum leaf area index = 4.2
[b] MAP = mean annual precipitation (400mm)

Increasing the peak LAI for the 60 cm cover showed a 15 to 30 percent reduction in average annual drainage for the 100 year simulation period (Table 5-1). This result is consistent with previous water balance analyses where LAI was evaluated over a range of peak values (Golder, 2004).

## 6.0 LONG-TERM REPORTING AND INTEGRATION WITH COMPLEMENTARY CONDITIONS

Condition 75 requires that the CCPE for the leach and waste rock stockpiles be completed within 3 years of approval of the work plan, and Condition 32 of the DP-27 Settlement Agreement requires that the CCPE for the tailing impoundments be completed within 5 years of approval of the work plan (NMED 2003a and 2003b). Condition 89 must be completed within 4 years of approval of DP-1341 and is required to have information relative to cover effectiveness (NMED 2003a). The cover effectiveness (i.e. drainage) information developed under Condition 75 (DP-1341) and Condition 31 of the DP-27 Settlement Agreement will be used to support the alternatives analysis required by Condition 89 of DP-1341.

Additional chemical and physical analyses of cover materials at Tyrone, required under Conditions 76 and 79 of DP-1341 and Condition 29 of the DP-27 Settlement Agreement, will be included once the data are available. It is estimated that a complete set of results would be available following cover placement on the stockpile and tailing impoundment test plots for the leach ore and wasterock stockpiles as well as additional borrow materials information collected for the SBMI. Pertinent cover materials information will be updated in the subsequent annual reports associated with the CCPE.

The CCPE shall be updated annually with available data from the cover and revegetation test plot studies conducted as part of Condition 76 of DP-1341 and Condition 29 of the DP-27 Settlement Agreement, and other applicable studies, when available. Tyrone proposes to combine the annual updates associated with Condition 75 (DP-1341) and Condition 31 of the DP-27 Settlement Agreement as the mechanism for reporting all information from the comprehensive cover performance evaluations as well as the cover and revegetation test plots required by Condition 76 (DP-1341) and Condition 29 of the DP-27 Settlement Agreement for DP-27. In total, this work will facilitate a feasibility evaluation of the proposed and alternative covers and will verify the sufficiency of the ultimate cover design with respect to the WQA and WQCC Regulations.

## 7.0 REFERENCES


ASTM D 2325-68 (94). Standard Test Method For Capillary-Moisture Relationships For Coarse- And Medium-Textured Soils By Porous Plate Apparatus.

ASTM D 2434-68. Test Method for Permeability of Granular Soils (Constant Head).

ASTM D 2487-90. Rock Fragment Content.

Asner, G.P. 1998. Biophysical and biochemical sources of variability in canopy reflectance. Remote Sens. Environ 64:234-253.

Ayers, R.S., and D.W. Westcot. 1989. Water quality for agriculture. FAO Irrigation and Drainage Paper No.29, Rev. 1. Rome.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial plant ecology, second edition. The Benjamin/Cummings Publishing Company, Inc., Menlo Park, California.

Blake, G.R., and K.H. Hartge. 1986. Particle Density. In: Methods of Soil Analysis. Part 1-Physical and Mineralogical Methods, 2nd Edition. A. Klute (ed). Agron. 9. Soil Sci. Soc. Am., Madison, WI.

Böhm, W. 1979. Methods of studying root systems. Springer-Verlag. Berlin. 188 pp.

Bouwer, H., and R.C. Rice. 1984. Hydraulic properties of stony vadose zone. Groundwater 22:696-705.

Brady, N.C. 1974. The nature and properties of soils. Eighth Edition. MacMillan publishing Company, New York.

Campbell, G.S. and J. M. Norman. 1998. An Introduction to Environmental Biophysics. Springer-Verlag, New York.

Carsel, R. F. and R. S. Parrish. 1988. "Developing joint probability distributions of soil water retention characteristics." Water Resour. Res. 24: 755-769.

Clark, P. E., and M. S. Seyfried. 2001. Point sampling for leaf area index in sagebrush steppe communities. J. Range Manage. 54: 589-594.

Cline, J.F., D.W. Ursek., and W.H. Rickard. 1977. Comparison of soil water used by a sagebrush-bunchgrass and a cheatgrass community. J.Range. Manage. 30:199-201.

Daniel B Stephens & Associated (DBS&A). 1997a. Preliminary material characterization, Tyrone Mine Closure/closeout. Prepared for Phelps Dodge Tyrone, Inc., Tyrone, New Mexico.

DBS&A. 1997b. Supplemental material characterization, Tyrone Mine Closure/closeout. Prepared for Phelps Dodge Tyrone, Inc., Tyrone, New Mexico.

DBS&A. 1997c. Closure/Closeout Plan, Tyrone Mine. Prepared for Phelps Dodge Tyrone Inc., Tyrone, New Mexico.

DBS&A. 1999a. Cover design status report, Tyrone Mine. Prepared for Phelps Dodge Tyrone, Inc., Tyrone, New Mexico.

DBS&A. 1999b. Interim technical standards for revegetation success, Tyrone and Little Rock Mines. Prepared for Phelps Dodge Tyrone, Inc., Tyrone, New Mexico.

Dunn, A.J., and G.R. Mehuys. 1984. Relationship between gravel content of soils and saturated hydraulic conductivity in laboratory tests. In: D.M. Kral (ed.) Erosion and Productivity of Soils Containing Rock Fragments. SSSA Special Pub. No. 13. Soil Sci. Soc. Am., Madison, WI.

Fayer, M.S. 2000. UNSAT-H Version 3.0: Unsaturated soil water and heat flow model. PNL-13249, U.S. Department of Energy, Pacific Northwest Laboratory, Richland, Washington.

Freeze, A.R., and J.A. Cherry. 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Gardner, W.H. 1986. Water Content. In: Methods of Soil Analysis. Part 1-Physical and Mineralogical Methods, 2nd Edition. A. Klute (ed). Agron. 9. Soil Sci. Soc. Am., Madison, WI.

Gardner, W.R. 1983. Soil properties and efficient water use: An overview in limitations to efficient water use in crop production. ASA, Inc., Madison, Wisconsin.

Golder Associates, Inc. 2004. Little Rock Mine Cover Design Report and Test Plot Work Plan. Prepared for Phelps Dodge Tyrone, Inc., Tyrone, New Mexico.

Heitschmidt, R.K., R.J. Ansley, S.L. Dowhower, P.W. Jacoby and D.L. Price. 1988. Some observations from the excavation of honey mesquite root systems. J. Range Mgmt. 41:227-231.

Hillel, D., 1998. Environmental soil physics. Academic Press, San Diego, California.

Jackson. R.B., J. Canadell, H.A. Mooney, O.E. Sala, and E.D. Schulze. 1996. A global analysis of root distributions for terrestrial biomes. Oecologia. 108:389-411.

Lapitan, R.L., and W.J. Parton. 1996. Seasonal variabilities in the distribution of microclimatic factors and evapotranspiration in a shortgrass steppe. Agr. and Forest Meteor. 79: 113-130.

Lee, C.A. and W.K. Lauenroth. 1994. Spatial distributions of grass and shrub root systems in the shortgrass steppe. Am. Midl. Nat. 132:117-123.

Mackie-Dawson, L.A., and D. Atkinson. 1991. Methodology for the study of roots in field experiments and the interpretation of results. p 25-47. In D. Atkinson. (ed) Plant root growth: an ecological perspective. Blackwell Sci. Publ., London.

McCord, J.T. 1991. Application of second-type boundaries in unsaturated flow modeling. Water Resources Research 27:3257-3260.

Mining and Minerals Division. 1996. Draft closeout plan guidelines for existing mines. Mining Act Reclamation Bureau, Santa Fe, NM. April 30.

Montaña, C., B. Cavagnaro, and O. Briones. 1995. Soil water use by co-existing shrubs and grasses in the Southern Chihuahaun Desert, Mexico. J. Arid Environments 31:1-13

Moore, R.T., and N.E. West. 1973. Distribution of galleta roots and rhizomes at two Utah sites. J. Range Mgmt. 26:34-36.l

Moorhead, D.L., Reynolds, J.F., and P. Fonteyn. 1989. Patterns of stratified soil water loss in a Chihuahuan desert community. Soil Science. 148:244-249.

National Climatic Data Center (NCDC). Western U.S. climate historical data summaries. Western Regional Climate Center http://www.wrcc.sage.dri.edu/. Accessed January 1999.

New Mexico Environment Department (NMED). 2003a. Supplemental Discharge Permit for Closure DP 1341, Phelps Dodge Tyrone, Inc., Tyrone Mines Facility.

NMED. 2003b. Settlement Agreement of Discharge Permit for Closure DP 27, Phelps Dodge Tyrone, Inc., Tyrone Mines Facility.

NMED. 2003c. Supplemental Discharge Permit for Closure DP 1340, Chino Mines Company.

PDTI. 2000. Closure/Closeout Plan for the Little Rock Mine, Grant County, New Mexico.

PDTI. 2002. Copper Mountain Stockpile Reclamation, Revised Plan and Status Report, Deadman Canyon Area. Phelps Dodge Tyrone Inc. Grant County, New Mexico.

PDTI. 2003. Reclamation plan, Copper Mountain Pit expansion project. Phelps Dodge Tyrone, Inc., Grant County, New Mexico.

Peace, J. L., P. J. Knight, T. S. Ashton, and T. J. Goering. 2004. Vegetation study in Support of the Design and Optimization of Vegetative Soil Covers. Prepared for Sandia National Laboratories, Albuquerque, NM.

Rawls, W.J., D.L. Brakensiek, and K.E. Saxton. 1982. Estimating soil water properties. Transactions ASAE 25:1316-1320, 1325

Ritchie, J.T. 1981. Soil water availability. Plant Soil 58:327-338.

Rundel, P., and P.S. Nobel. 1991. Sturcture and function in desert root systems. In Plant root growth: an ecological perspective. Blackwell Sci. Publ., London. Pg. 349-378.

S.S. Papadopulos and Associates (SSP&A). 2001. Analysis of paleo-climate and climate forcing information for New Mexico and implications for modeling in the Middle Rio Grande water supply study. Memo to the New Mexico Interstate Stream Commission and U.S. Army Corp of Engineers. http://www.seo.state.nm.us/water-info/mrgwss/p3-nm-climate-memo.pdf. 22 pp.

Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. Agricultural Handbook No. 60. USDA-Agricultural Research Service. US Government Printing Office, Washington, D.C.

Saxton.K.E., Rawls,W.J., Romberger.J.S., Papendick,R.I. 1985. Contributions from Agric. Res. Serv., USDA, in cooperation with the College of Agric. and Home Economics, Agric. Res. Center, Washington State Univ., Pullman, WA 99164. Scientific Paper no. 6911. June 1995.

Schulze, E.D., H.A. Mooney, O.W. Sala, E. Jobbagy, N. Butchmann., G. Bauer, J. Canadell, R.B. Jackson., J. Loreti, M. Oesterheld and J.R. Ehleringer. 1996. Rooting depth, water availability, and vegetation cover along an aridity gradient in Patagonia. Oecologia. 108:503-511.

Scurlock, J. M. O., G. P. Asner, and S. T. Gower. 2001. Worldwide Historical Estimates of Leaf Area Index, 1932-2000. Prepared by the Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Sims, P.L. and J.S. Singh. 1978. The structure and function of ten western North American grasslands. Journal of Ecology. 66:547-572.

Soil Survey Staff. 1993. Soil survey manual. Handbook No. 18, 2nd ed. USDA-Soil Conservation Service. US Government Printing Office, Washington, D.C.

van Genuchten, M Th. 1978. Calculating the unsaturated conductivity with a new closed-form analytical model. Research Repot 78-WR-08. Depth. Of Civil Eng., Princeton Univ., Princeton, New jersey. 63 pp.

van Genuchten, M Th. 1980. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J. 44:892-898.

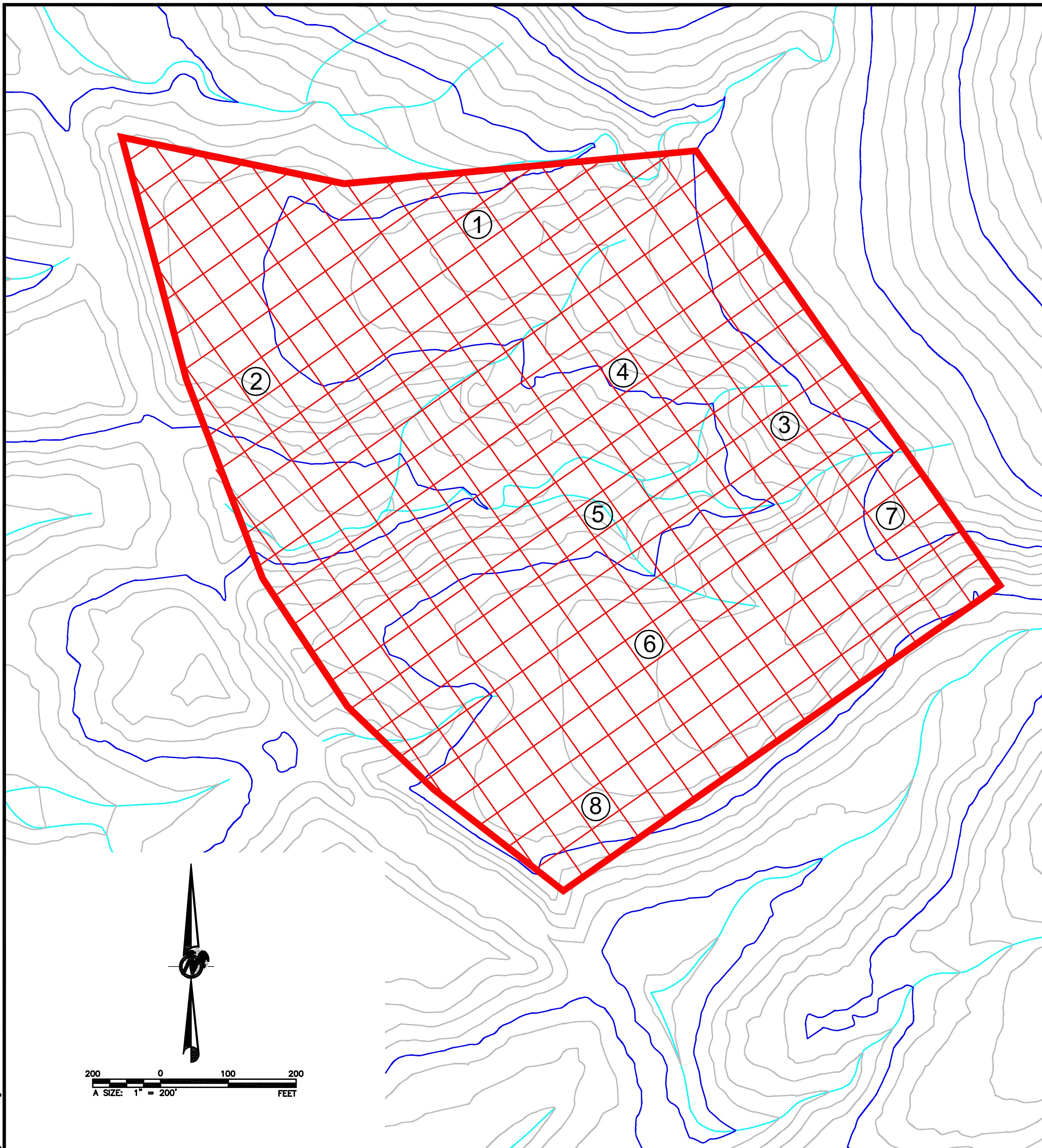
van Genuchten, M Th., F.J. Leij, S.R. Yates and J.R. Williams. 1991. RETC4 Code for quantifying the hydraulic functions of unsaturated soils. U.S. Salinity Laboratory, USDA-ARS, Riverside, CA.

Welles, J. M., and J. M. Norman. 1991. Instrument for indirect measurement of canopy structure. Agron. J. 83: 818-825.

Whittaker, R.H. and Niering, W.A. 1975. Vegetation of the Santa Catalina Mountains, Arizona: Biomass, production, and diversity along the elevation gradient. Ecology 56: 771-790.

# APPENDIX A

# LEAF AREA SAMPLE SITES, PHOTOGRAPHS AND FIELD DATA

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① SAMPLE PLOT

PROJECT

phelps dodge TYRONE Inc.

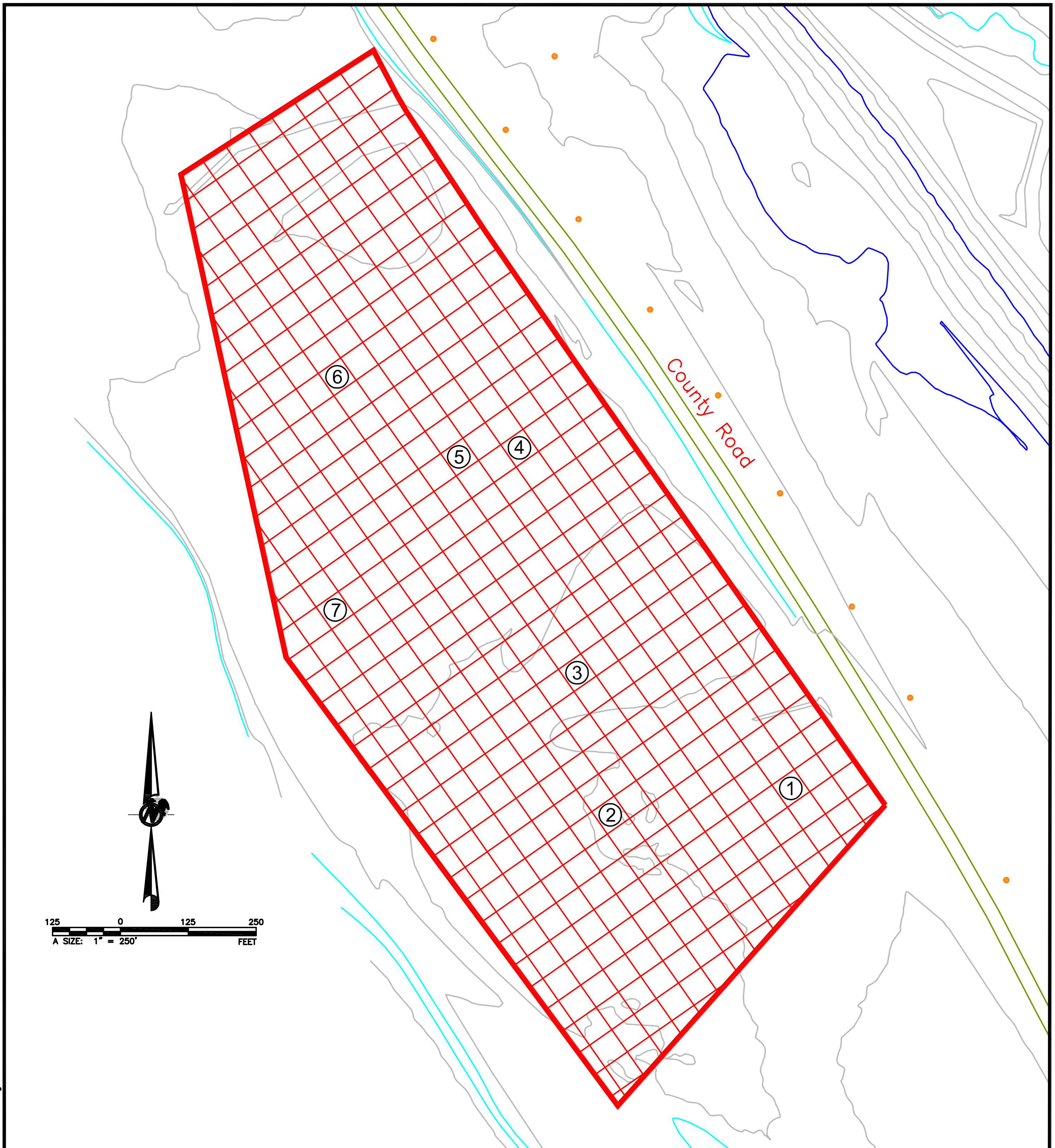
PHELPS DODGE TYRONE INC.
GRANT COUNTY, NEW MEXICO

TITLE

**LEAF AREA PLOTS**
**TYRONE REFERENCE AREA**

Golder Associates
Albuquerque, New Mexico

| | | | | |
|---|---|---|---|---|
| PROJECT No. | | 043-2328 | FILE No. | 0432328 |
| DESIGN | LM | 01/25/05 | SCALE AS SHOWN | REV. A |
| CADD | CM | 01/25/05 | **FIGURE A-1** | |
| CHECK | DR | 01/31/05 | | |
| REVIEW | -- | DATE | | |




① SAMPLE PLOT

| | | | | | |
|---|---|---|---|---|---|
| PROJECT | phelps dodge TYRONE Inc. | PHELPS DODGE TYRONE INC.<br>GRANT COUNTY, NEW MEXICO | | | |
| TITLE | LEAF AREA PLOTS<br>EXCLUSION AREA<br>SOUTH MAIN REPOSITORY | | | | |
| Golder Associates<br>Albuquerque, New Mexico | PROJECT No. | | 043-2328 | FILE No. | 0432328 |
| | DESIGN | LM | 01/25/05 | SCALE AS SHOWN | REV. A |
| | CADD | CM | 01/25/05 | FIGURE A-2 | |
| | CHECK | DR | 01/31/05 | | |
| | REVIEW | -- | DATE | | |

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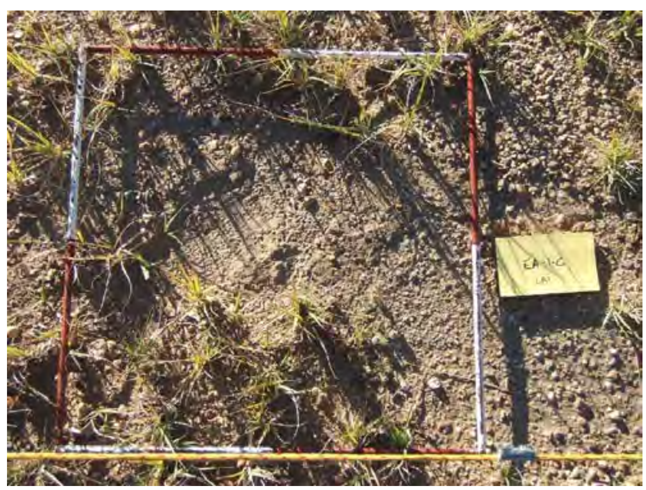

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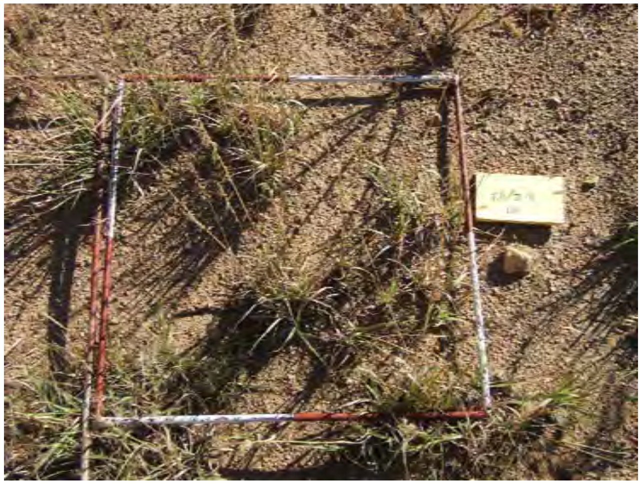

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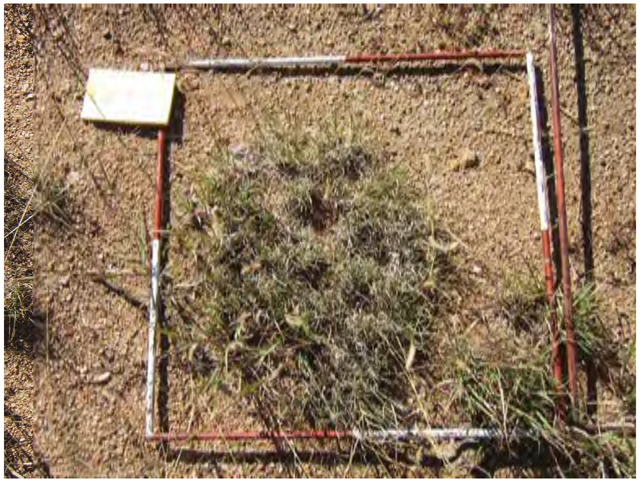

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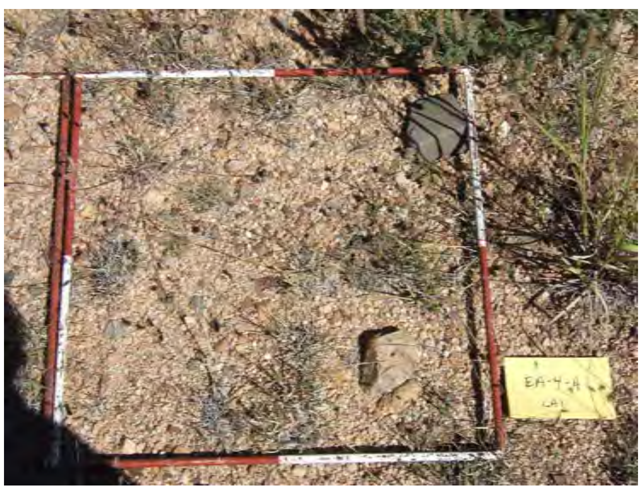

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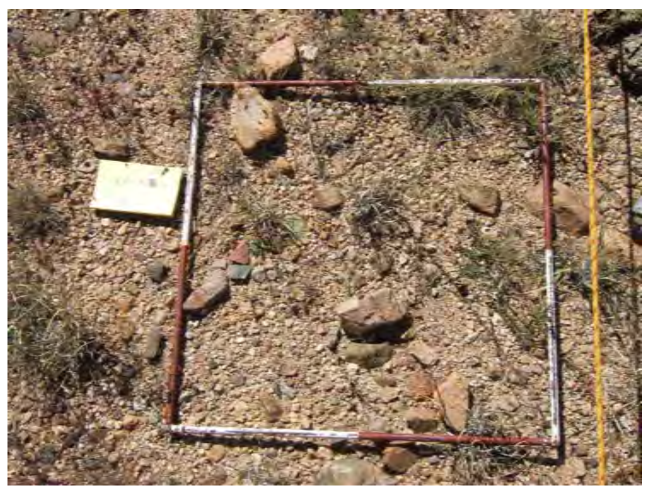

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Quadrat EA5A (10/06/04)

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Plot EA6; Tyrone Repository (10/06/04)

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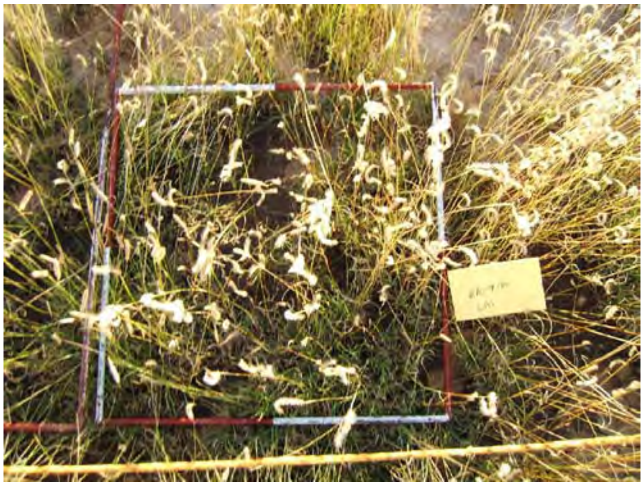

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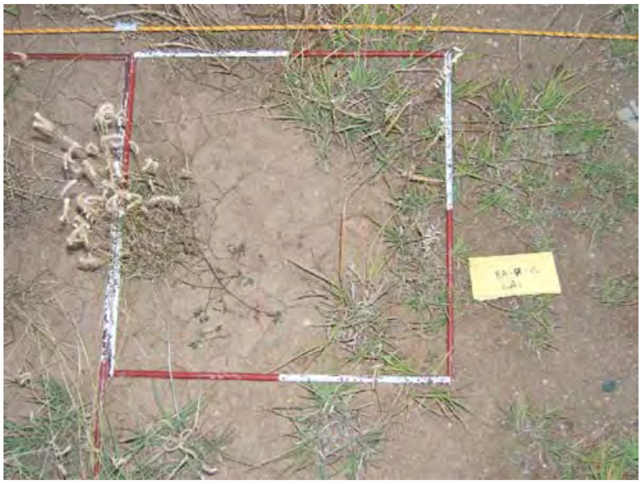

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Plot TR1; Reference Area

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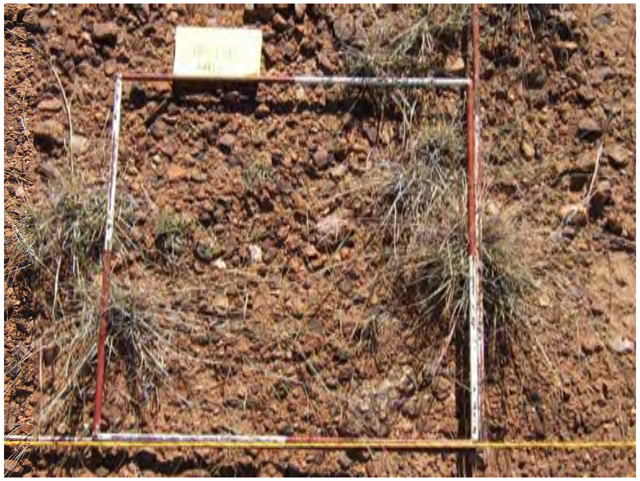
Quadrat TR1B (10/03/04)



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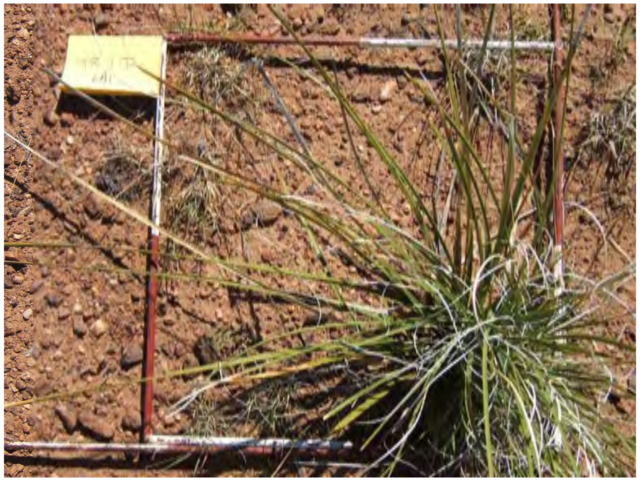

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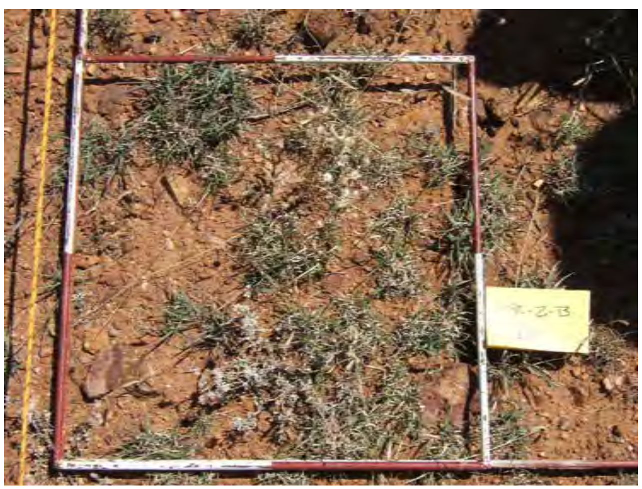

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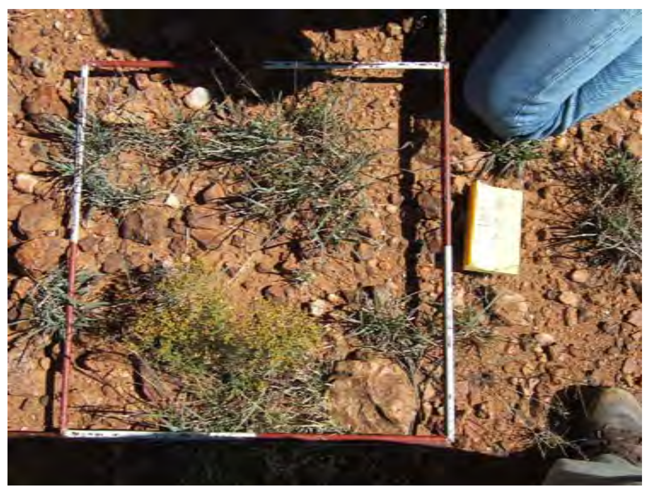

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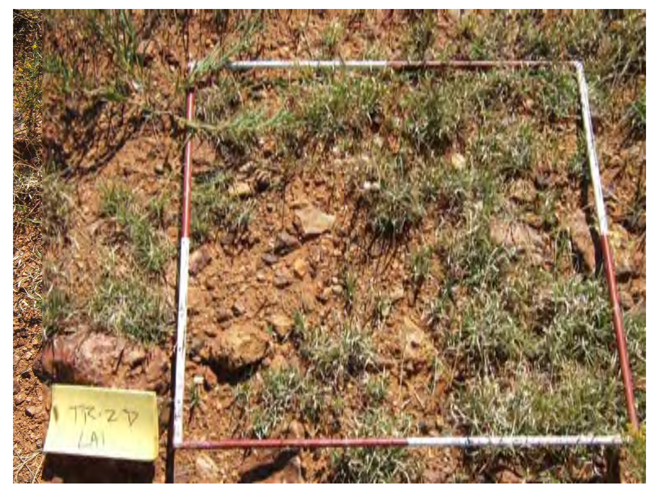


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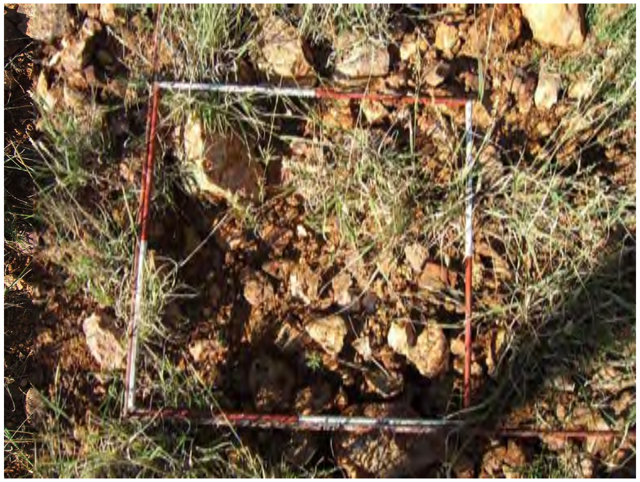

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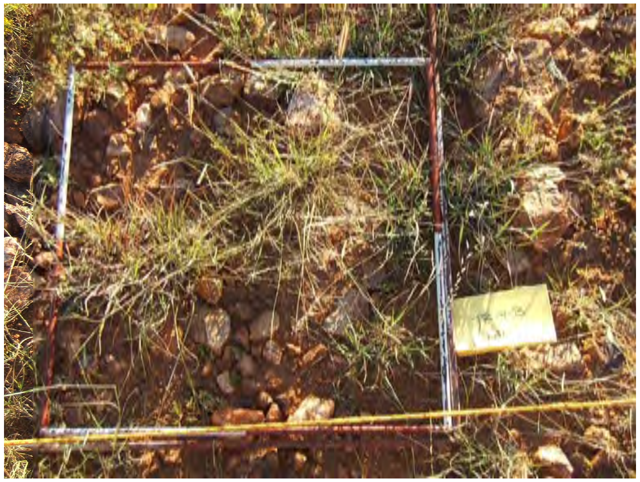

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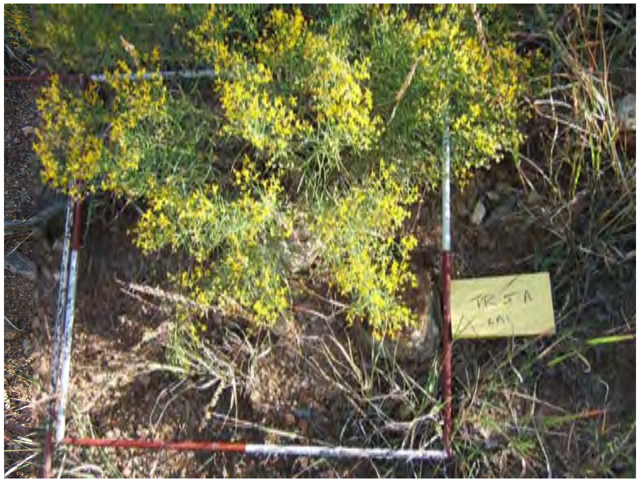


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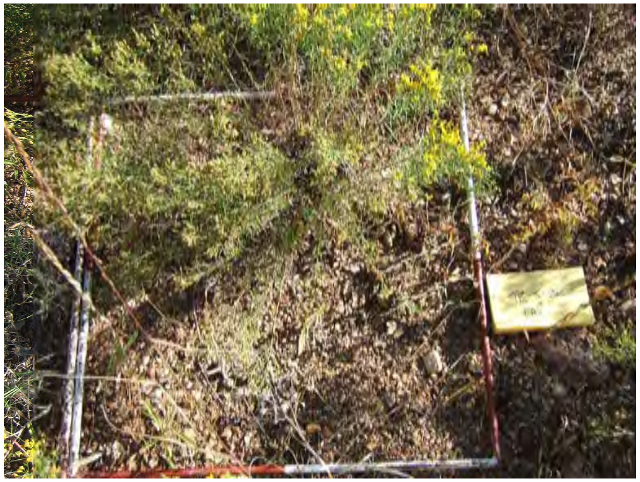

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Quadrat TR5C (10/04/04)

Quadrat TR5D (10/04/04)

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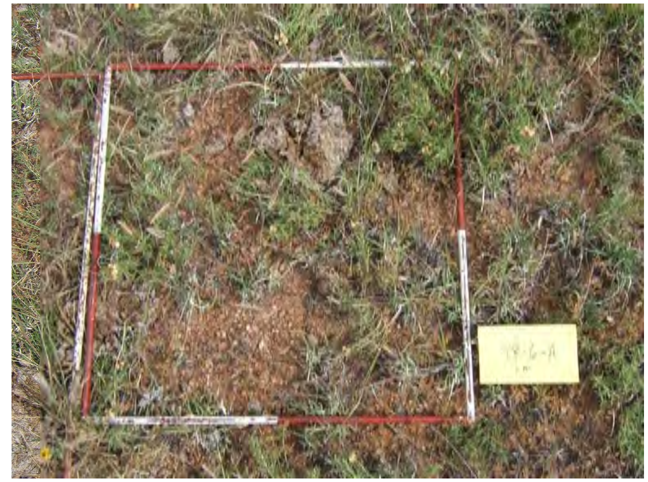

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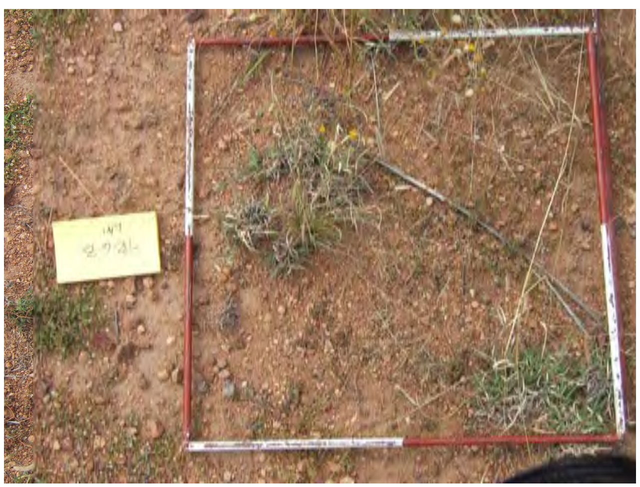

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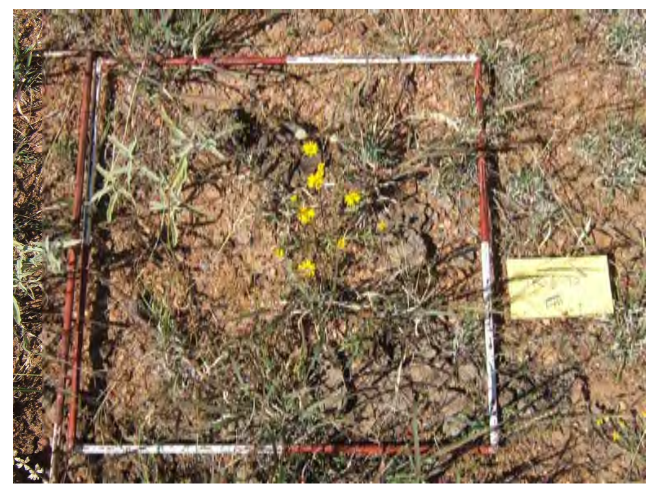

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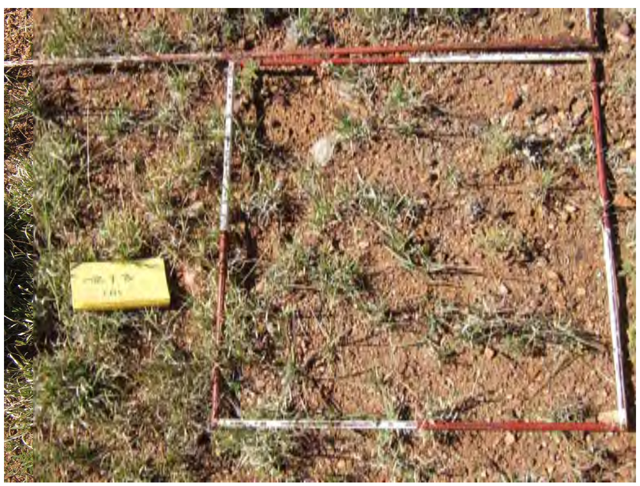
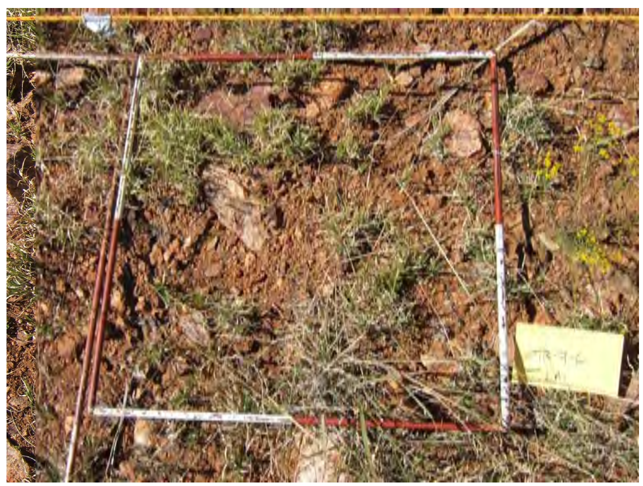
Plot TR7; Reference Area (10/05/04)

Quadrat TR7A (10/05/04)



Quadrat TR7B (10/05/04)



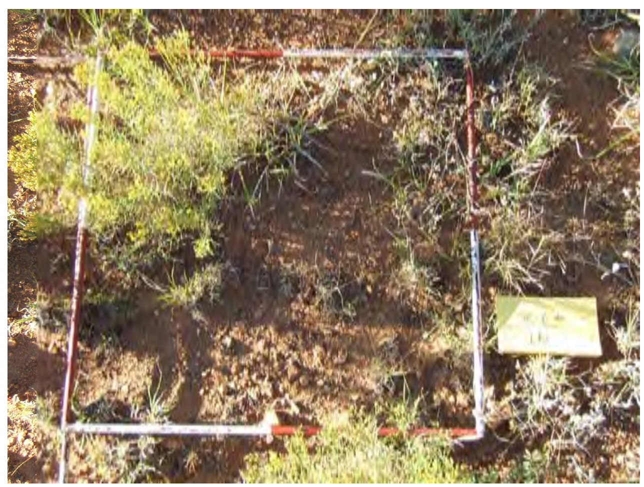
Quadrat TR7C (10/05/04)

Quadrat TR7D (10/05/04)

Plot TR8; Reference Area (10/05/04)

Quadrat TR8A (10/05/04)

Quadrat TR8B (10/05/04)



Quadrat TR8C (10/05/04)

Quadrat TR8D (10/05/04)

LAI - Vegetation Plot Form

Golder Associates

| Location: TR | Plot No.: 1 | Transect No.: | Date: 10/4/04 | By: DR |
|---|---|---|---|---|

**Quadrant No.: A**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOBA | 4 | 6 | 1 |
| Total | 4 | 6 | |
| Rock | 70.5 | 69.5 | |
| Litter | 0.5 | 0.5 | |
| Bare Soil | 25 | 24 | |

**Quadrant No.: B**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOER | 4 | 41 | 5 |
| STPA | 0.2 | 5 | 1 |
| CHPR | T | 1 | 1 |
| BOHI | 0.2 | 1 | 2 |
| EVSE | T | 1 | 1 |
| Total | 4.3 | 49 | |
| Rock | 87.7 | 44.5 | |
| Litter | 7 | 6 | |
| Bare Soil | 1 | 0.5 | |

**Quadrant No.: C**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOER | 2 | 7 | 3 |
| ARSC | 1 | 5 | 1 |
| EVSE | T | 1 | 3 |
| FEBA | 0.1 | 0.5 | 1 |
| Total | 3.1 | 13.5 | |
| Rock | 89.4 | 81 | |
| Litter | 0.5 | 0.5 | |
| Bare Soil | 7 | 5 | |

**Quadrant No.: D**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 0.5 | 3 | 4 |
| NOMI | 2.5 | 90 | 1 |
| SINE | T | 0.1 | 1 |
| BOHI | 1.5 | 4 | 4 |
| ERSE | T | 0.2 | 2 |
| Total | 4.5 | 97.3 | |
| Rock | 67.5 | 1.6 | |
| Litter | 3 | 0.1 | |
| Bare Soil | 25 | 1 | |

Comments

✓ entered into database

LAI - Vegetation Plot Form

Golder Associates

| Location: TR | Plot No.: 2 | Transect No.: | Date: 10/4/04 | By: DR |
|---|---|---|---|---|

**Quadrant No.: A**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOGR2 | 2 | 10 | |
| SPFE | 0.1 | 4 | |
| HIMU | 3 | 25 | |
| PODL | T | 0.5 | |
| PAVI | T | 0.5 | |
| STPA | T | 0.2 | |
| | | | |
| | | | |
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| | | | |
| | | | |
| Total | 5.2 | 35.2 | |
| Rock | 88.3 | 58.8 | |
| Litter | 2.5 | 3 | |
| Bare Soil | 4 | 3 | |

**Quadrant No.: B**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 1 | 4 | 6 |
| BOGR2 | 2 | 18 | 16 |
| HAGR | T | 4 | 1 |
| TERWR | 0.1 | 3 | 1 |
| POOL | T | 1 | 2 |
| | | | |
| | | | |
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| | | | |
| | | | |
| | | | |
| Total | 3.1 | 30 | |
| Rock | 76.9 | 56 | |
| Litter | 2 | 2 | |
| Bare Soil | 18 | 12 | |

**Quadrant No.: C**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 1.6 | 13 | 15 |
| HIBE | 0.3 | 25 | 6 |
| PRGL | 0.2 | 5 | 1 |
| GUSA | 0.1 | 8 | 1 |
| | | | |
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| | | | |
| | | | |
| | | | |
| Total | 2.2 | 25 | |
| Rock | 85.3 | 65 | |
| Litter | 0.5 | 1 | |
| Bare Soil | 12 | 9 | |

**Quadrant No.: D**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOGR | 7.5 | 2 | 3 |
| HIBE | 8 | 26 | 32 |
| MELA | T | 2 | 1 |
| ACAN | T | 0.2 | 1 |
| | | | |
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| | | | |
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| | | | |
| | | | |
| Total | 8.5 | 28 | |
| Rock | 81.5 | 66 | |
| Litter | 1 | 1 | |
| Bare Soil | 9 | 5 | |

Comments

B, C Hvy Browse - Rabbits

LAI - Vegetation Plot Form

Golder Associates

| Location: TR | Plot No.: 3 | Transect No.: | Date: 10/4/04 | By: DR |
|---|---|---|---|---|

**Quadrant No.: A**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| HIBE | 1 | 5 | 10 |
| PAVI | T | 0.1 | 2 |
| ARAD | T | 0.2 | 6 |
| DALO | T | 2.5 | 3 |
| FLWR | 0.1 | 1 | 1 |
| | | | |
| POOL | 0.1 | 0.8 | 70 |
| CHPR | T | 0.2 | 4 |
| CRCR | T | 0.1 | 3 |
| Total | 1.3 | 9 | |
| Rock | 84.7 | 80 | |
| Litter | 4 | 9 | |
| Bare Soil | 10 | 9 | |

**Quadrant No.: B**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| PAPA | 1 | 8 | 4 |
| BOGU | 0.5 | 5 | 2 |
| | | | |
| | | | |
| PRGL | 1.5 | 85 | 1 |
| ALAN | 0.1 | 7 | 1 |
| | | | |
| TPCO | T | T | 2 |
| POOL | T | 0.5 | 2 |
| CIUN | 0.1 | 0 | 1 |
| Total | 3.2 | 100 | |
| Rock | 15 | 0 | |
| Litter | 15 | 0 | |
| Bare Soil | 66.8 | 0 | |

**Quadrant No.: C**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| HIBI | 0.2 | 2 | 6 |
| | | | |
| NOMI | 0.5 | 100 | 1 |
| Total | 0.7 | 100 | |
| Rock | 24 | 0 | |
| Litter | 20 | 0 | |
| Bare Soil | 55.3 | 0 | |

**Quadrant No.: D**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| HIMU | 1 | 4 | 3 |
| BOGU | 2 | 7 | 4 |
| HIBE | 0.2 | 1 | 2 |
| DALO | T | 1 | 2 |
| POOL | T | 1.5 | 2 |
| Total | 3.2 | 14.5 | |
| Rock | 89.3 | 83 | |
| Litter | 0.5 | 0.5 | |
| Bare Soil | 7 | 2 | |

Comments
Quad C & D strongly sloping W. Aspect

LAI - Vegetation Plot Form

Golder Associates

Location: TR | Plot No.: 4 | Transect No.: | Date: 10/4/04 | By: DR

Quadrant No.: A

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 0.6 | 6 | 2 |
| | | | |
| PRGL | 0.4 | 80 | 2 |
| PEOL | T | 1 | 1 |
| ACAN | T | 0.1 | 1 |
| SOVL | T | 0.5 | 1 |
| Total | 1 | 85 | |
| Rock | 10 | 10 | |
| Litter | 45 | 3 | |
| Bare Soil | 44 | 2 | |

Quadrant No.: B

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 1 | 12 | 3 |
| BOGR2 | 0.2 | 6 | 2 |
| ARDI | 0.5 | 4 | 1 |
| BOER | 0.5 | 6 | 1 |
| SPAE | 0.1 | 1 | 1 |
| POSL | T | 1.5 | 4 |
| CHER | T | 2 | 6 |
| ACAN | T | 3 | 1 |
| Total | 1.3 | 38 | |
| Rock | 74.7 | 40 | |
| Litter | 4 | 5 | |
| Bare Soil | 20 | 25 | |

Quadrant No.: C

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 0.5 | 4 | 2 |
| | | | |
| GUSA | 1.5 | 25 | 2 |
| Total | 2 | 28 | |
| Rock | 85 | 64 | |
| Litter | 3 | 2 | |
| Bare Soil | 10 | 6 | |

Quadrant No.: D (No Pix)

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOGR2 | 0.3 | 4 | 2 |
| BOCU | 1 | 7 | 1 |
| | | | |
| FRWR | 0.4 | 3 | 3 |
| ACAN | 0.3 | 80 | 10 |
| GUSA | 0.4 | 5 | 1 |
| Total | 2.3 | 95 | |
| Rock | 59.7 | 3 | |
| Litter | 3 | 1 | |
| Bare Soil | 35 | 1 | |

Comments

LAI - Vegetation Plot Form

Golder Associates

| Location: TR | Plot No.: 5 | Transect No.: | Date: 10/5/04 | By: DR |
|---|---|---|---|---|

Quadrant No.: A

| Species | Basal % | Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 0.6 | 7 | 5 |
| GUSA | 1 | 40 | 1 |
| MOPE | T | 0.1 | 2 |
| Total | 1.6 | 43 | |
| Rock | 78.4 | 51 | |
| Litter | 12 | 2 | |
| Bare Soil | 8 | 4 | |

Quadrant No.: B

| Species | Basal % | Canopy % | # Ind. |
|---|---|---|---|
| ARSC | T | 0.1 | 1 |
| GUSA | 1.5 | 60 | 1 |
| MOPE | 0.1 | 2 | 12 |
| SASU | 0.1 | 4 | 5 |
| SEVI | T | T | 1 |
| CHPR | T | T | 3 |
| Total | 1.7 | 62 | |
| Rock | 90.3 | 35 | |
| Litter | 4 | 1 | |
| Bare Soil | 4 | 2 | |

Quadrant No.: C

| Species | Basal % | Canopy % | # Ind. |
|---|---|---|---|
| BOGR? | 0.7 | 6 | 2 |
| BOCU | 0.9 | 10 | 4 |
| MOPE | 0.1 | 1.5 | 14 |
| MILI | T | 0.1 | 2 |
| CHPR | T | 0.1 | 3 |
| POOL | T | 0.1 | 1 |
| TAAU | T | 0.1 | 1 |
| SPFE | T | 0.1 | 2 |
| Total | 1.7 | 15 | |
| Rock | 72.3 | 65 | |
| Litter | 20 | 15 | |
| Bare Soil | 6 | 5 | |

Quadrant No.: D

| Species | Basal % | Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 0.1 | 2 | 2 |
| POA SP | 2.0 | 20 | 5 |
| MOPE | 0.1 | 1 | 10 |
| ASGER | 0.1 | 6 | 4 |
| Total | 2.3 | 24 | |
| Rock | 18.7 | 14 | |
| Litter | 75 | 60 | |
| Bare Soil | 4 | 2 | |

Comments

Quads are just above a small drainage C/D - 15% slope under Gray oak

SEVI - Setaria viridis - green bristlegrass

MILI - Mirabilis linearis

LAI - Vegetation Plot Form

Golder Associates

| Location: TR | Plot No.: 6 | Transect No.: | Date: 10/5/04 | By: DR |
|---|---|---|---|---|

**Quadrant No.: A**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOGR2 | 1.7 | 17 | 27 |
| ERAG Annual | | | |
| ZIGR | 1 | 23 | 5 |
| CHPR | 0.1 | 1 | 34 |
| DRMO | T | T | 6 |
| Total | 2.8 | 38 | |
| Rock | 80.2 | 50 | |
| Litter | 10 | 7 | |
| Bare Soil | 7 | 5 | |

**Quadrant No.: B**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOGR2 | 1.5 | 15 | 8 |
| ARPU | 0.2 | 3 | 1 |
| CHPR | 0.1 | 2 | 13 |
| DRMO | T | 0.2 | 20 |
| Total | 1.8 | 20 | |
| Rock | 68.2 | 57 | |
| Litter | 5 | 3 | |
| Bare Soil | 25 | 20 | |

**Quadrant No.: C**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOGR2 | 2.2 | 20 | 10 |
| ARPU | 1 | 5 | 2 |
| CHPR | T | 0.2 | 50 |
| DRMO | T | 0.3 | 25 |
| Total | 3.2 | 25 | |
| Rock | 59 | 44 | |
| Litter | 8 | 6 | |
| Bare Soil | 29.8 | 25 | |

**Quadrant No.: D**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 1.8 | 18 | 7 |
| BOGR2 | 1.1 | 11 | 7 |
| ARPU | 0.1 | 1.5 | 1 |
| HAGR | 0.1 | 6 | 1 |
| SOEL | T | 3 | 1 |
| CHPR | T | 3 | 15 |
| DRMO | T | 1 | 4 |
| SASU | T | 1 | 1 |
| TAAU | T | T | 2 |
| Total | 3.2 | 37 | |
| Rock | 66.8 | 52 | |
| Litter | 20 | 10 | |
| Bare Soil | 10 | 1 | |

Comments

Fan Remnant

DRMO - Drymaria molluginea

LAI - Vegetation Plot Form

Golder Associates

| Location: TR | Plot No.: 7 | Transect No.: | Date: | By: |
|---|---|---|---|---|

**Quadrant No.: A**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOGR2 | 1 | 14 | 9 |
| ARSE | T | T | 1 |
| PAOB | T | 0.1 | 2 |
| ERWR | T | 1.5 | 1 |
| GUSA | 1.5 | 35 | 1 |
| POOL | T | 1 | 6 |
| MAIA | T | 0.3 | 1 |
| SPFE | T | 4 | 2 |
| Total | 2.6 | 40 | |
| Rock | 52.4 | 30 | |
| Litter | 5 | 2 | |
| Bare Soil | 40 | 28 | |

**Quadrant No.: B**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| HIBE | 0.5 | 5 | 7 |
| BOCU | 0.3 | 5 | 4 |
| BOGR2 | 1.6 | 15 | 19 |
| ARSE | T | T | 2 |
| ACAN | T | 0.3 | 2 |
| ERWR | 0.1 | 1.5 | 1 |
| COVI | 1 | 1 | 1 |
| SPFE | T | 2.5 | 2 |
| POOL | T | 0.1 | 9 |
| Total | 3.5 | 27 | |
| Rock | 82.5 | 62 | |
| Litter | 2 | 1 | |
| Bare Soil | 12 | 10 | |

**Quadrant No.: C**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| HIBE | 3.0 | 32 | 26 |
| BOCU | 0.4 | 6 | 1 |
| BOGR2 | T | 0.2 | 1 |
| RVSE | T | 1.6 | 1 |
| POOL | T | 0.6 | 5 |
| Total | 3.4 | 38 | |
| Rock | 86.6 | 58 | |
| Litter | 3 | 2 | |
| Bare Soil | 7 | 2 | |

**Quadrant No.: D**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| STIPA | 1.1 | 9 | 2 |
| BOGR2 | 0.1 | 0.7 | 3 |
| | | | |
| ACAN | 0.2 | 20 | 3 |
| Total | 1.3 | 25 | |
| Rock | 88 | 70 | |
| Litter | 6.7 | 3 | |
| Bare Soil | 4 | 2 | |

Comments

COVI - Coreanthera vivipera

Quad B - POOL/ARSE Not Collected - too small

COVI - 5cm in diameter

LAI - Vegetation Plot Form

Golder Associates

| Location: TR | Plot No.: 8 | Transect No.: | Date: | By: |
|---|---|---|---|---|

**Quadrant No.: A**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOGR2 | 0.7 | 7 | 5 |
| BOER | 4 | 55 | 7 |
| BOCU | 0.7 | 7 | 2 |
| MECA | T | 0.2 | 2 |
| ERVE | T | 1 | 1 |
| Total | 5.4 | 82 | |
| Rock | 88.6 | 15 | |
| Litter | 4 | 2 | |
| Bare Soil | 2 | 1 | |

**Quadrant No.: B**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 1.4 | 12 | 5 |
| HIBE | 0.1 | 2 | 2 |
| BOGR | 1.2 | 11 | 6 |
| ARPU | 0.1 | 1.5 | 1 |
| ACAN | T | 3.5 | 2 |
| Total | 2.8 | 30 | |
| Rock | 75.2 | 52 | |
| Litter | 5 | 3 | |
| Bare Soil | 17 | 15 | |

**Quadrant No.: C**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOGR2 | 1.2 | 12 | 10 |
| ARPU | 0.5 | 2.5 | 2 |
| BOBA | 0.7 | 6 | 2 |
| | | | |
| ACAN | T | 0.5 | 1 |
| GUSA | 1 | 25 | 1 |
| ERUR | 0.2 | 8.5 | 2 |
| Total | 3.6 | 33 | |
| Rock | 20 | 15 | |
| Litter | 4 | 2 | |
| Bare Soil | 72.4 | 50 | |

**Quadrant No.: D**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOGR2 | 11 | 11 | 10 |
| | | | |
| | | | |
| GUSA | 5 | 30 | 2 |
| Total | 6.1 | 37 | |
| Rock | 46.9 | 31 | |
| Litter | 12 | 7 | |
| Bare Soil | 35 | 25 | |

Comments

Quad A - Meca - not collected
[illegible] dry

LAI - Vegetation Plot Form

Golder Associates

| Location: EA | Plot No.: 1 | Transect No.: | Date: | By: |
|---|---|---|---|---|

**Quadrant No.: A**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 1 | 6.5 | 7 |
| BOBA | T | 0.1 | 1 |
| SPCR | T | 0.5 | 1 |
| HAGR | T | 0.5 | 2 |
| DECO | 0.1 | 5 | 1 |
| Total | 1.2 | 17.6 | |
| Rock | 32 | 30 | |
| Litter | 1.5 | 1 | |
| Bare Soil | 65.3 | 56.4 | |

**Quadrant No.: C**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 2.4 | 20 | 25 |
| | | | |
| DECO | T | 4 | 1 |
| Total | 2.4 | 23 | |
| Rock | 20 | 17 | |
| Litter | 1 | 1 | |
| Bare Soil | 76.6 | 59 | |

**Quadrant No.:**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| Total | | | |
| Rock | | | |
| Litter | | | |
| Bare Soil | | | |

**Quadrant No.:**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| Total | | | |
| Rock | | | |
| Litter | | | |
| Bare Soil | | | |

Comments

Quad C - Being impacted by sedimentation & small gully cutting into tailing

LAI - Vegetation Plot Form

Location: EA | Plot No.: 2 | Transect No.: | Date: 10/6/04 | By: DR

Quadrant No.: A

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 0.3 | 2 | 22 |
| BOGR | 2.5 | 26 | 2 |
| BOBA | T | 0.1 | 1 |
| HABR | T | 0.5 | 1 |
| POOL | T | 0.1 | 1 |
| Total | 2.8 | 27 | |
| Rock | 12 | 8 | |
| Litter | 1 | 0.5 | |
| Bare Soil | 84.2 | 64 | |

Quadrant No.: C

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 3.3 | 33 | 19 |
| SPAI | 0.7 | 6 | 6 |
| Total | 4.0 | 39 | |
| Rock | 86 | 54.5 | |
| Litter | 2 | 1.5 | |
| Bare Soil | 8 | 5 | |

Quadrant No.: D

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOGR | 4.0 | 40 | 15 |
| BOCU | 0.8 | 9 | 7 |
| | | | |
| DACO | 1 | 1.5 | 2 |
| Total | 4.8 | 47 | |
| Rock | 50 | 32 | |
| Litter | 5 | 1 | |
| Bare Soil | 40.2 | 20 | |

Quadrant No.:

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| Total | | | |
| Rock | | | |
| Litter | | | |
| Bare Soil | | | |

Comments

LAI - Vegetation Plot Form

Golder Associates

| Location: EA | Plot No.: 3 | Transect No.: | Date: | By: DR |
|---|---|---|---|---|

Quadrant No.: A

| Species | Cover: Basal % | Cover: Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 1.5 | 17 | 8 |
| BOHI | 0.5 | 5 | 1 |
| SPCR | 0.1 | 3 | 2 |
| | | | |
| DACO | T | 3 | 1 |
| HAGR | T | 0.5 | 2 |
| Total | 1.7 | 25 | |
| Rock | 76.3 | 63 | |
| Litter | 2 | 2 | |
| Bare Soil | 20 | 10 | |

Quadrant No.: C

| Species | Cover: Basal % | Cover: Canopy % | # Ind. |
|---|---|---|---|
| BOCU | 2.0 | 20 | 20 |
| BOHI | 1.6 | 11 | 11 |
| | | | |
| | | | |
| DACO | T | 1 | 1 |
| Total | 3.6 | 29 | |
| Rock | 79.4 | 61 | |
| Litter | 2 | 2 | |
| Bare Soil | 15 | 8 | |

Quadrant No.:

| Species | Cover: Basal % | Cover: Canopy % | # Ind. |
|---|---|---|---|
| Total | | | |
| Rock | | | |
| Litter | | | |
| Bare Soil | | | |

Quadrant No.:

| Species | Cover: Basal % | Cover: Canopy % | # Ind. |
|---|---|---|---|
| Total | | | |
| Rock | | | |
| Litter | | | |
| Bare Soil | | | |

Comments

LAI - Vegetation Plot Form

Golder Associates

| Location: EA | Plot No.: 41 | Transect No.: | Date: 10/6/04 | By: DR |
|---|---|---|---|---|

**Quadrant No.: A**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOHI | 1.8 | 19 | 14 |
| ARPU | 0.2 | 2.5 | 4 |
| TRLO | T | 2 | 2 |
| LOWR | T | 0.1 | 1 |
| Total | 2.0 | 22 | |
| Rock | 97 | 77.5 | |
| Litter | 1 | 0.5 | |
| Bare Soil | Ø | Ø | |

**Quadrant No.: C**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOHI | 1 | 9 | 5 |
| BOCU | 0.2 | 1 | 2 |
| ARAD | T | 0.1 | 5 |
| ARPU | 1 | 4 | 3 |
| LOWR | 0.1 | 1.5 | 4 |
| HAGR | T | T | 2 |
| DACO | T | 2 | 1 |
| Total | 2.4 | 16 | |
| Rock | 94.6 | 82 | |
| Litter | 3 | 2 | |
| Bare Soil | Ø | Ø | |

**Quadrant No.: D**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOHI | 4 | 50 | 11 |
| ARSC | 1.6 | 12 | 2 |
| ARPU | 0.1 | 3 | 1 |
| ARHA | 1 | 12 | 1 |
| LOWR | 1 | 11 | 2 |
| Total | 7.7 | 80 | |
| Rock | 72.3 | 18 | |
| Litter | 20 | 2 | |
| Bare Soil | Ø | Ø | |

**Quadrant No.:**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| Total | | | |
| Rock | | | |
| Litter | | | |
| Bare Soil | | | |

Comments

LAI - Vegetation Plot Form

Golder Associates

| Location: EA | Plot No.: 5 | Transect No.: | Date: 10/6/04 | By: DR |
|---|---|---|---|---|

**Quadrant No.: A**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOBA | .2 | 1.5 | 1 |
| ARPU | 0.8 | 6 | 6 |
| BOHI | 1.2 | 12 | 5 |
| BOCU | 0.2 | 1.8 | 3 |
| DALE | 1.2 | 65 | 8 |
| ASNU | 0.2 | 10 | 1 |
| Total | 5.6 | 89.5 | |
| Rock | 93.4 | 9 | |
| Litter | 1 | 1.5 | |
| Bare Soil | 0 | 0 | |

**Quadrant No.: C**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOHI | 1.4 | 22 | 6 |
| ARHA | 0.9 | 18 | 9 |
| ARAD | T | 0.1 | 15 |
| | | | |
| DELO | T | 4 | 1 |
| HAGR | T | 2 | 6 |
| LAUR | 2.0 | 20 | 9 |
| POOL | T | 0.1 | 5 |
| CHFR | T | 0.1 | |
| Total | 4.3 | 66 | |
| Rock | 70.7 | 23 | |
| Litter | 5 | 7 | |
| Bare Soil | 20 | 4 | |

**Quadrant No.:**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| Total | | | |
| Rock | | | |
| Litter | | | |
| Bare Soil | | | |

**Quadrant No.:**

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| Total | | | |
| Rock | | | |
| Litter | | | |
| Bare Soil | | | |

Comments

LAI - Vegetation Plot Form

Golder Associates

| Location: EA | Plot No.: 6 | Transect No.: | Date: 10/6/04 | By: DR |
|---|---|---|---|---|

Quadrant No.: A

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOGR | 1 | 10 | 15 |
| BOHI | 1 | 6 | 6 |
| ARPU | 0.2 | 1 | 1 |
| ASNU | T | 1 | 1 |
| HAGR | T | T | 1 |
| Total | 2.2 | 18 | |
| Rock | 94.8 | 80.5 | |
| Litter | 1 | 0.5 | |
| Bare Soil | 2 | 1 | |

Quadrant No.: C

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| BOGR | 1.5 | 9 | 4 |
| ARAD | T | 0.1 | 5 |
| BOHI | 2 | 8 | 2 |
| DACO | T | 1.5 | 3 |
| HAGR | T | 0.5 | 4 |
| LONR | T | 0.5 | 1 |
| Total | 3.5 | 20 | |
| Rock | 95.5 | 78.5 | |
| Litter | 1 | 1.5 | |
| Bare Soil | Ø | Ø | |

Quadrant No.:

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| Total | | | |
| Rock | | | |
| Litter | | | |
| Bare Soil | | | |

Quadrant No.:

| Species | Cover Basal % | Cover Canopy % | # Ind. |
|---|---|---|---|
| Total | | | |
| Rock | | | |
| Litter | | | |
| Bare Soil | | | |

Comments

# LAI - Vegetation Plot Form

Golder Associates

| Location: EA | Plot No.: 7 | Transect No.: | Date: 10/6/04 | By: DR |
|---|---|---|---|---|

**Quadrant No.: A**

| Species | Cover: Basal % | Cover: Canopy % | # Ind. |
|---|---|---|---|
| BOGR | 8.5 | 8.5 | 24 |
| Total | 8.5 | 8.5 | |
| Rock | Ø | Ø | |
| Litter | 2 | 4 | |
| Bare Soil | 89.5 | 14 | |

**Quadrant No.: C**

| Species | Cover: Basal % | Cover: Canopy % | # Ind. |
|---|---|---|---|
| BOGR | 1.2 | 9 | 8 |
| BOCU | 1.3 | 6 | 1 |
| SPCR | 0.1 | 1 | 1 |
| RHSF | T | 0.5 | 1 |
| Total | 2.8 | 15.5 | |
| Rock | 3 | 2 | |
| Litter | 2 | 1 | |
| Bare Soil | 92.2 | 81.5 | |

**Quadrant No.:**

| Species | Cover: Basal % | Cover: Canopy % | # Ind. |
|---|---|---|---|
| Total | | | |
| Rock | | | |
| Litter | | | |
| Bare Soil | | | |

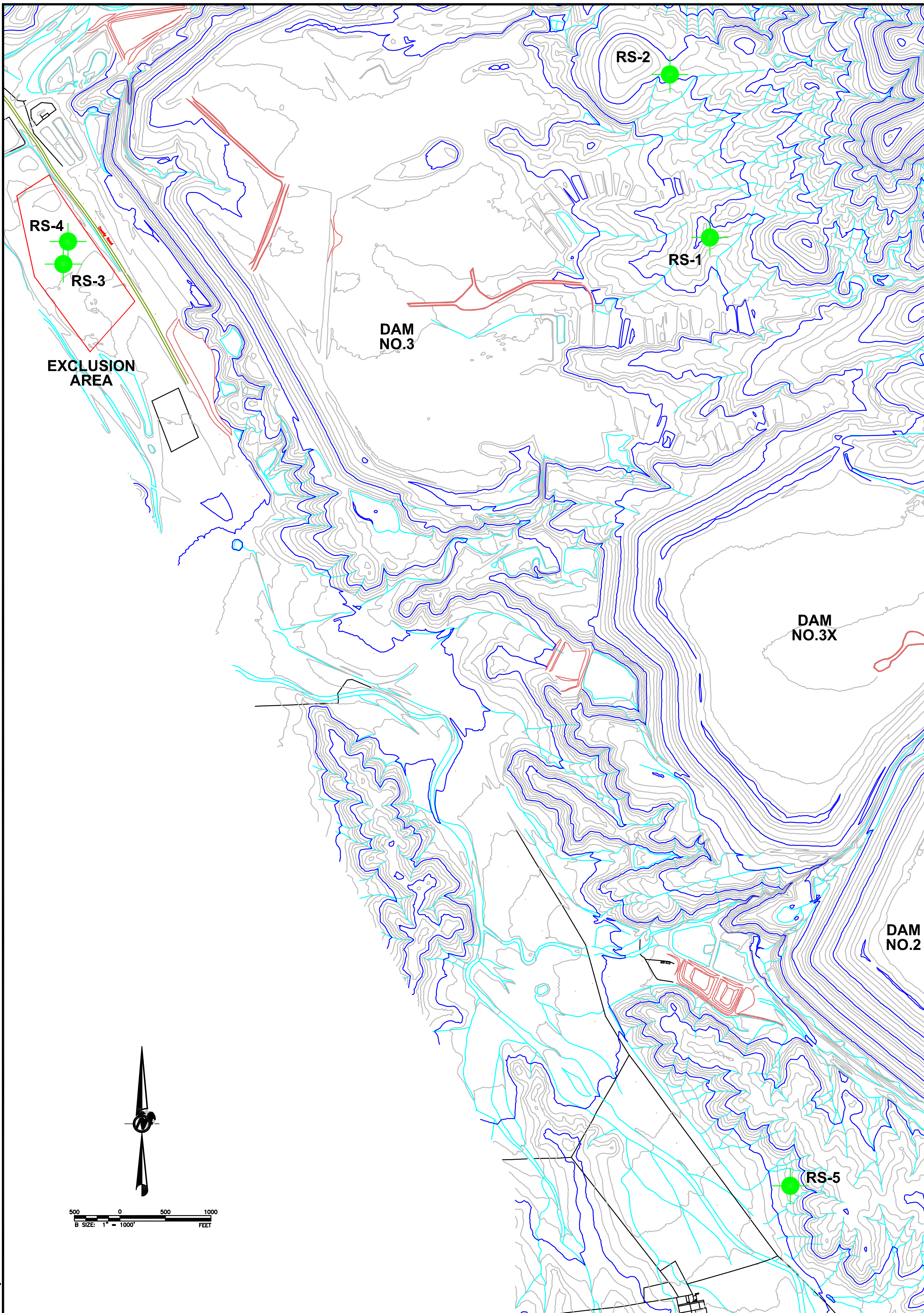
**Quadrant No.:**

| Species | Cover: Basal % | Cover: Canopy % | # Ind. |
|---|---|---|---|
| Total | | | |
| Rock | | | |
| Litter | | | |
| Bare Soil | | | |

Comments

# APPENDIX B

# ROOT DENSITY DATA




ROOT STUDY TRENCHES

PROJECT

phelps dodge TYRONE Inc.

PHELPS DODGE TYRONE INC.
GRANT COUNTY, NEW MEXICO

TITLE

**ROOT STUDY SAMPLE PITS**
**MANGAS VALLEY-TYRONE MINE**

Golder Associates
Albuquerque, New Mexico

| | | | | |
|---|---|---|---|---|
| PROJECT No. | | 043-2328 | FILE No. | 0432328 |
| DESIGN | LM | 01/25/05 | SCALE AS SHOWN | REV. A |
| CADD | CM | 01/25/05 | **FIGURE B-1** | |
| CHECK | DR | 01/31/05 | | |
| REVIEW | -- | DATE | | |

K:\2004 Projects\043-2328 Tyr CCPE\CCPE study areas.dwg

**TABLE B-1. ABBREVIATED SOIL DESCRIPTION FOR RS-1**

| Horizon | Depth (Inches) | USDA Texture Class | Rock Fragment (vol. %) | Moist Color | Soil Structure | Reaction With 10% HCl |
|---|---|---|---|---|---|---|
| A | 0 - 4 | COSL | 30 | 10YR 3/2 | 2 vf gr | NE |
| Bt1 | 4 - 10 | CL | 20 | 7.5YR 3/3 | 1 c sbk | NE |
| Bt2 | 10 -26 | C | 18 | 7.5YR 3/4 | 3 c abk | NE |
| BC | 26 -32 | SCL | 60 | 7.5YR 4/4 | ma | SL |
| C1 | 32 - 36 | SCL | 61 | 5YR 4/6 | ma | VI |
| C2 | 36 - 60 + | SL | 30 | 5YR 5/6 | ma | NE |

**TABLE B-2. ABBREVIATED SOIL DESCRIPTION FOR RS-2**

| Horizon | Depth (Inches) | USDA Texture Class | Rock Fragment (vol. %) | Moist Color | Soil Structure | Reaction With 10% HCl |
|---|---|---|---|---|---|---|
| A | 0 - 2 | SL | 21 | 10YR 3/4 | 2 vf gr | NE |
| Bt1 | 2 - 12 | CL | 33 | 5YR 4/4 | 2 c sbk | NE |
| Bt2 | 12 - 19 | SCL | 45 | 5YR 4/4 | 1 c sbk | NE |
| C | 19 - 50 + | LS | 43 | 7.5YR 4/4 | ma | NE |

**TABLE B-3. ABBREVIATED SOIL DESCRIPTION FOR RS-3**

| Horizon | Depth (Inches) | USDA Texture Class | Rock Fragment (vol. %) | Moist Color | Soil Structure | Reaction With 10% HCl |
|---|---|---|---|---|---|---|
| Fill 1 | 0 - 3 | SL | 33 | 10YR 3/4 | 1 m sbk | ST |
| Fill 2 | 3 - 11 | SL | 22 | 10YR 3/3 | 1 m sbk | NE |
| Fill 3 | 11 - 18 | LS | 23 | 10YR 4/3 | ma | NE |
| Fill 4 | 18 - 34 | SL | 38 | 10YR 4/3 | c | NE |
| Tailings | 34 - 40 + | SL | 0 | 10YR 7/3 | ma | NE |

**TABLE B-4. ABBREVIATED SOIL DESCRIPTION FOR RS-4**

| Horizon | Depth (Inches) | USDA Texture Class | Rock Fragment (vol. %) | Moist Color | Soil Structure | Reaction With 10% HCl |
|---|---|---|---|---|---|---|
| Fill 1 | 0 - 1 | SL | 21 | 10YR 3/3 | 1 vc pl | NE |
| Fill 2 | 1 - 40 | LCOS | 42 | 10YR 4/4 | ma | NE |
| Tailings | 40 + | FSL | 0 | 10YR 7/3 | ma | NE |

**TABLE B-5. ABBREVIATED SOIL DESCRIPTION FOR RS-5**

| Horizon | Depth (Inches) | USDA Texture Class | Rock Fragment (vol. %) | Moist Color | Soil Structure | Reaction With 10% HCl |
|---|---|---|---|---|---|---|
| A1 | 0 - 1 | SL | 26 | 10YR 3/3 | 2 vc pl | NE |
| A2 | 1 - 8 | SL | 15 | 10YR 3/2 | 1 m sbk | NE |
| C1 | 8 - 30 | LS | 22 | 10YR 3/4 | ma | NE |
| C2 | 30 - 41 | LS | 22 | 10YR 3/3 | ma | NE |
| C3 | 41 - 49+ | LS | 22 | 10YR 3/4 | ma | NE |

**ABBREVIATIONS**

| **Texture** | |
|---|---|
| S | Sand |
| LS | Loamy sand |
| SL | Sandy loam |
| SCL | Sandy clay loam |
| L | Loam |
| CL | Clay loam |
| SI | Silt |
| SIL | Silt loam |
| SICL | Silty clay loam |
| SIC | Silty clay |
| SC | Sandy clay |
| C | Clay |
| **Sand Modifiers** | |
| CO | Coarse |
| F | Fine |
| VF | Very Fine |
| **Coarse Fragments** | |
| GR | Gravelly |
| VGR | Very gravelly |
| EGR | Extremely gravelly |
| **Structure - Grade** | |
| 0 | Structureless |
| 1 | Weak |
| 2 | Moderate |
| 3 | Strong |

| **Structure - Size** | |
|---|---|
| 1 | Very fine or thin |
| 2 | Fine or thin |
| 3 | Medium |
| 4 | Coarse or Thick |
| 5 | Very coarse or thick |
| **Structure - Shape** | |
| GR | Granular |
| PL | Platy |
| PR | Prismatic |
| CPR | Columnar |
| ABK | Angular blocky |
| SBK | Sub-angular blocky |
| SGR | Single grain |
| MA | Massive |
| **Consistence** | |
| L | Loose |
| VFR | Very friable |
| FR | Friable |
| FI | Firm |
| VFI | Very firm |
| EFI | Extremely firm |
| **Effervescence** | |
| NE | No effervescence |
| SL | Slightly effervescence |
| ST | Strangely effervescence |
| VI | Violently effervescence |

**TABLE B-6. MEASURED ROOT DENSITY DISTRIBUTION FOR RS1A**

| Soil Depth cm bgs | Column Identification | | | | | | | | | | Average roots/dm$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | |
| 0-10 | 67 | 65 | 66 | 50 | 33 | 47 | 52 | 58 | 62 | 73 | 57.3 |
| 10-20 | 46 | 73 | 49 | 28 | 27 | 38 | 50 | 21 | 36 | 54 | 42.2 |
| 20-30 | 19 | 60 | 45 | 31 | 23 | 50 | 32 | 52 | 48 | 50 | 41.0 |
| 30-40 | 27 | 17 | 23 | 49 | 20 | 52 | 60 | 77 | 59 | 63 | 44.7 |
| 40-50 | 26 | 20 | 13 | 7 | 22 | 37 | 45 | 26 | 34 | 23 | 25.3 |
| 50-60 | 3 | 13 | 12 | 9 | 9 | 15 | 20 | 10 | 3 | 10 | 10.4 |
| 60-70 | 9 | 8 | 7 | 13 | 13 | 11 | 11 | 9 | 6 | 3 | 9.0 |
| 70-80 | 6 | 5 | 5 | 5 | 4 | 4 | 8 | 3 | 2 | 0 | 4.2 |
| 80-90 | y | 5 | 5 | 5 | 4 | 3 | 6 | 0 | 1 | 0 | 3.2 |
| 90-100 | 1 | 3 | 2 | 2 | 5 | 4 | 0 | 2 | 0 | 0 | 1.9 |

**TABLE B-7. MEASURED ROOT DENSITY DISTRIBUTION FOR RS2A**

| Soil Depth cm bgs | Column Identification | | | | | | | | | | Average roots/dm$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | |
| 0-10 | 50 | 52 | 54 | 87 | 42 | 46 | 69 | 66 | 63 | 73 | 60.2 |
| 10-20 | 16 | 28 | 43 | 28 | 28 | 46 | 33 | 26 | 29 | 24 | 30.1 |
| 20-30 | 69 | 26 | 13 | 37 | 45 | 45 | 42 | 31 | 13 | 12 | 33.3 |
| 30-40 | 24 | 5 | 3 | 12 | 19 | 6 | 18 | 1 | 0 | 0 | 8.8 |
| 40-50 | 0 | 0 | 0 | 4 | 0 | 1 | 2 | 0 | 0 | 0 | 0.7 |
| 50-60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0.2 |
| 60-70 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| 70-80 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 |
| 80-90 | 0 | 0 | 0 | 0 | 6 | 0 | 3 | 0 | 0 | 0 | 0.9 |
| 90-100 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 0.4 |

Notes: Each column of the grid was 10 cm in width
bgs = below ground surface
dm = decimeter

**TABLE B-8. MEASURED ROOT DENSITY DISTRIBUTION FOR RS2B**

| Soil Depth cm bgs | Column Identification | | | | | | | | | | Average roots/dm$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | |
| 0-10 | 65 | 61 | 57 | 42 | 64 | 44 | 59 | 60 | 55 | 32 | 53.9 |
| 10-20 | 22 | 33 | 31 | 43 | 44 | 39 | 44 | 41 | 34 | 44 | 37.5 |
| 20-30 | 12 | 6 | 14 | 6 | 8 | 16 | 27 | 28 | 22 | 15 | 15.4 |
| 30-40 | 3 | 3 | 7 | 1 | 1 | 2 | 4 | 11 | 11 | 0 | 4.3 |
| 40-50 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| 50-60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| 60-70 | 0 | 5 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0.6 |
| 70-80 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0.2 |
| 80-90 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| 90-100 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 2 | 0 | 0 | 0.6 |

**TABLE B-9. MEASURED ROOT DENSITY DISTRIBUTION FOR RS2C**

| Soil Depth cm bgs | Column Identification | | | | | | | | | | Average roots/dm$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | |
| 0-10 | 64 | 37 | 27 | 29 | 33 | 57 | 47 | 44 | 34 | 45 | 41.7 |
| 10-20 | 12 | 5 | 6 | 12 | 11 | 26 | 13 | 21 | 10 | 18 | 13.4 |
| 20-30 | 7 | 8 | 7 | 9 | 11 | 13 | 7 | 1 | 2 | 13 | 7.8 |
| 30-40 | 1 | 0 | 0 | 3 | 3 | 0 | 1 | 0 | 0 | 6 | 1.4 |
| 40-50 | 0 | 0 | 0 | 2 | 1 | 1 | 2 | 0 | 0 | 0 | 0.6 |
| 50-60 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0.5 |
| 60-70 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 3 | 0.7 |
| 70-80 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 |
| 80-90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.1 |
| 90-100 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 |

Notes: Each column of the grid was 10 cm in width
bgs = below ground surface
dm = decimeter

**TABLE B-10. MEASURED ROOT DENSITY DISTRIBUTION FOR RS3A**

| Soil Depth cm bgs | Column Identification | | | | | | | | | | Average roots/dm$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | |
| 0-10 | 41 | 51 | 37 | 34 | 50 | 65 | 58 | 16 | 40 | 53 | 44.5 |
| 10-20 | 21 | 28 | 21 | 33 | 30 | 23 | 6 | 6 | 7 | 23 | 19.8 |
| 20-30 | 13 | 14 | 24 | 10 | 13 | 10 | 9 | 5 | 9 | 18 | 12.5 |
| 30-40 | 0 | 1 | 1 | 19 | 24 | 13 | 3 | 7 | 2 | 7 | 7.7 |
| 40-50 | 0 | 1 | 1 | 1 | 6 | 6 | 5 | 5 | 3 | 4 | 3.2 |
| 50-60 | 1 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 8 | 1.6 |
| 60-70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 5 | 1.0 |
| 70-80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0.3 |
| 80-90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| 90-100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |

**TABLE B-11. MEASURED ROOT DENSITY DISTRIBUTION FOR RS3B**

| Soil Depth cm bgs | Column Identification | | | | | | | | | | Average roots/dm$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | |
| 0-10 | 43 | 38 | 51 | 44 | 40 | 69 | 35 | 27 | 37 | 35 | 41.9 |
| 10-20 | 18 | 20 | 17 | 19 | 28 | 17 | 9 | 13 | 8 | 9 | 15.8 |
| 20-30 | 16 | 9 | 1 | 22 | 28 | 8 | 8 | 15 | 12 | 11 | 13.0 |
| 30-40 | 9 | 7 | 3 | 13 | 12 | 6 | 16 | 12 | 5 | 10 | 9.3 |
| 40-50 | 13 | 9 | 12 | 35 | 9 | 12 | 9 | 12 | 8 | 3 | 12.2 |
| 50-60 | 11 | 2 | 11 | 25 | 15 | 6 | 17 | 6 | 4 | 4 | 10.1 |
| 60-70 | 4 | 0 | 9 | 9 | 18 | 5 | 18 | 1 | 1 | 5 | 7.0 |
| 70-80 | 15 | 10 | 9 | 4 | 6 | 0 | 3 | 1 | 4 | 8 | 6.0 |
| 80-90 | 5 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.0 |
| 90-100 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 |

Notes: each column of the grid was 10 cm in width
bgs = below ground surface
dm = decimeter

**TABLE B-12. MEASURED ROOT DENSITY DISTRIBUTION FOR RS3C**

| Soil Depth cm bgs | Column Identification | | | | | | | | | | Average roots/dm$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | |
| 0-10 | 49 | 48 | 74 | 46 | 32 | 65 | 50 | 40 | 37 | 38 | 47.9 |
| 10-20 | 23 | 19 | 18 | 17 | 25 | 23 | 19 | 12 | 23 | 13 | 19.2 |
| 20-30 | 10 | 7 | 9 | 14 | 16 | 18 | 16 | 3 | 11 | 11 | 11.5 |
| 30-40 | 8 | 5 | 3 | 2 | 4 | 8 | 11 | 2 | 5 | 4 | 5.2 |
| 40-50 | 8 | 1 | 0 | 0 | 3 | 9 | 3 | 1 | 4 | 4 | 3.3 |
| 50-60 | 0 | 1 | 0 | 1 | 2 | 5 | 2 | 4 | 4 | 7 | 2.6 |
| 60-70 | 0 | 0 | 1 | 2 | 3 | 9 | 3 | 7 | 3 | 11 | 3.9 |
| 70-80 | 1 | 0 | 3 | 2 | 3 | 0 | 3 | 5 | 0 | 2 | 1.9 |
| 80-90 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| 90-100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |

**TABLE B-13. MEASURED ROOT DENSITY DISTRIBUTION FOR RS4A**

| Soil Depth cm bgs | Column Identification | | | | | | | | | | Average roots/dm$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | |
| 0-10 | 21 | 24 | 26 | 49 | 39 | 17 | 12 | 28 | 25 | 33 | 27.4 |
| 10-20 | 13 | 22 | 4 | 4 | 9 | 10 | 7 | 15 | 15 | 11 | 11.0 |
| 20-30 | 3 | 4 | 4 | 1 | 0 | 5 | 12 | 3 | 1 | 0 | 3.3 |
| 30-40 | 0 | 1 | 1 | 1 | 0 | 1 | 3 | 11 | 0 | 0 | 1.8 |
| 40-50 | 2 | 5 | 2 | 0 | 4 | 1 | 0 | 1 | 5 | 0 | 2.0 |
| 50-60 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 2 | 3 | 1 | 1.3 |
| 60-70 | 1 | 0 | 6 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 1.0 |
| 70-80 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 2 | 0.8 |
| 80-90 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0.5 |
| 90-100 | 1 | 3 | 2 | 1 | 3 | 0 | 0 | 0 | 7 | 2 | 1.9 |

Notes: each column of the grid was 10 cm in width
bgs = below ground surface
dm = decimeter

**TABLE B-14. MEASURED ROOT DENSITY DISTRIBUTION FOR RS4B**

| Soil Depth cm bgs | Column Identification | | | | | | | | | | Average roots/dm² |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | |
| 0-10 | 45 | 47 | 26 | 29 | 50 | 75 | 35 | 28 | 30 | 33 | 39.8 |
| 10-20 | 16 | 34 | 18 | 28 | 27 | 22 | 36 | 7 | 23 | 17 | 22.8 |
| 20-30 | 8 | 10 | 19 | 12 | 7 | 20 | 8 | 7 | 10 | 9 | 11.0 |
| 30-40 | 3 | 6 | 5 | 5 | 12 | 5 | 14 | 6 | 10 | 5 | 7.1 |
| 40-50 | 4 | 9 | 4 | 5 | 2 | 6 | 8 | 10 | 6 | 6 | 6.0 |
| 50-60 | 2 | 2 | 3 | 5 | 5 | 2 | 0 | 4 | 2 | 2 | 2.7 |
| 60-70 | 2 | 5 | 1 | 0 | 1 | 3 | 6 | 2 | 1 | 4 | 2.5 |
| 70-80 | 0 | 2 | 1 | 1 | 2 | 4 | 5 | 7 | 5 | 0 | 2.7 |
| 80-90 | 2 | 0 | 1 | 0 | 5 | 6 | 5 | 1 | 3 | 1 | 2.4 |
| 90-100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |

**TABLE B-15. MEASURED ROOT DENSITY DISTRIBUTION FOR RS4C**

| Soil Depth cm bgs | Column Identification | | | | | | | | | | Average roots/dm² |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | |
| 0-10 | 49 | 53 | 39 | 49 | 42 | 26 | 52 | 57 | 28 | 22 | 41.7 |
| 10-20 | 20 | 28 | 12 | 12 | 8 | 12 | 6 | 11 | 12 | 3 | 12.4 |
| 20-30 | 3 | 8 | 2 | 5 | 2 | 3 | 2 | 3 | 2 | 0 | 3.0 |
| 30-40 | 3 | 0 | 3 | 1 | 2 | 2 | 3 | 1 | 0 | 1 | 1.6 |
| 40-50 | 2 | 5 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 1 | 1.4 |
| 50-60 | 4 | 1 | 3 | 1 | 1 | 0 | 0 | 3 | 1 | 3 | 1.7 |
| 60-70 | 0 | 1 | 3 | 0 | 1 | 0 | 0 | 3 | 2 | 1 | 1.1 |
| 70-80 | 0 | 1 | 2 | 3 | 3 | 1 | 4 | 0 | 2 | 1 | 1.7 |
| 80-90 | 0 | 3 | 2 | 0 | 2 | 0 | 0 | 2 | 2 | 1 | 1.2 |
| 90-100 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 0.5 |

Notes: each column of the grid was 10 cm in width
bgs = below ground surface
dm = decimeter

**TABLE B-16. MEASURED ROOT DENSITY DISTRIBUTION FOR RS5A**

| Soil Depth cm bgs | Column Identification | | | | | | | | | | Average roots/dm$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | |
| 0-10 | 74 | 51 | 87 | 88 | 83 | 88 | 67 | 91 | 123 | 104 | 85.6 |
| 10-20 | 29 | 14 | 14 | 27 | 70 | 65 | 69 | 75 | 71 | 64 | 49.8 |
| 20-30 | 10 | 21 | 22 | 13 | 27 | 17 | 37 | 61 | 41 | 45 | 29.4 |
| 30-40 | 14 | 14 | 14 | 14 | 17 | 25 | 24 | 21 | 20 | 3 | 16.6 |
| 40-50 | 7 | 33 | 17 | 12 | 7 | 10 | 12 | 5 | 14 | 11 | 12.8 |
| 50-60 | 3 | 10 | 14 | 5 | 13 | 3 | 5 | 3 | 5 | 2 | 6.3 |
| 60-70 | 10 | 9 | 5 | 10 | 6 | 2 | 5 | 1 | 4 | 2 | 5.4 |
| 70-80 | 16 | 2 | 6 | 12 | 2 | 1 | 6 | 6 | 1 | 0 | 5.2 |
| 80-90 | 2 | 1 | 4 | 2 | 2 | 3 | 4 | 1 | 3 | 6 | 2.8 |
| 90-100 | 3 | 0 | 1 | 2 | 1 | 1 | 0 | 2 | 2 | 1 | 1.3 |

**TABLE B-17. MEASURED ROOT DENSITY DISTRIBUTION FOR RS5B**

| Soil Depth cm bgs | Column Identification | | | | | | | | | | Average roots/dm$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | |
| 0-10 | 61 | 63 | 45 | 75 | 70 | 73 | 76 | 74 | 41 | 35 | 61.3 |
| 10-20 | 31 | 38 | 25 | 18 | 56 | 30 | 36 | 26 | 23 | 21 | 30.4 |
| 20-30 | 21 | 19 | 22 | 16 | 22 | 14 | 17 | 13 | 29 | 25 | 19.8 |
| 30-40 | 9 | 19 | 10 | 12 | 14 | 4 | 13 | 14 | 19 | 13 | 12.7 |
| 40-50 | 14 | 8 | 6 | 3 | 8 | 8 | 12 | 10 | 18 | 9 | 9.6 |
| 50-60 | 15 | 11 | 6 | 9 | 8 | 6 | 9 | 11 | 21 | 12 | 10.8 |
| 60-70 | 8 | 7 | 4 | 5 | 7 | 11 | 9 | 6 | 13 | 9 | 7.9 |
| 70-80 | 4 | 9 | 5 | 5 | 6 | 5 | 7 | 7 | 4 | 5 | 5.7 |
| 80-90 | 3 | 15 | 12 | 6 | 4 | 10 | 1 | 16 | 2 | 3 | 7.2 |
| 90-100 | 3 | 8 | 12 | 15 | 5 | 7 | 9 | 15 | 7 | 5 | 8.6 |

Notes: each column of the grid was 10 cm in width
bgs = below ground surface
dm = decimeter

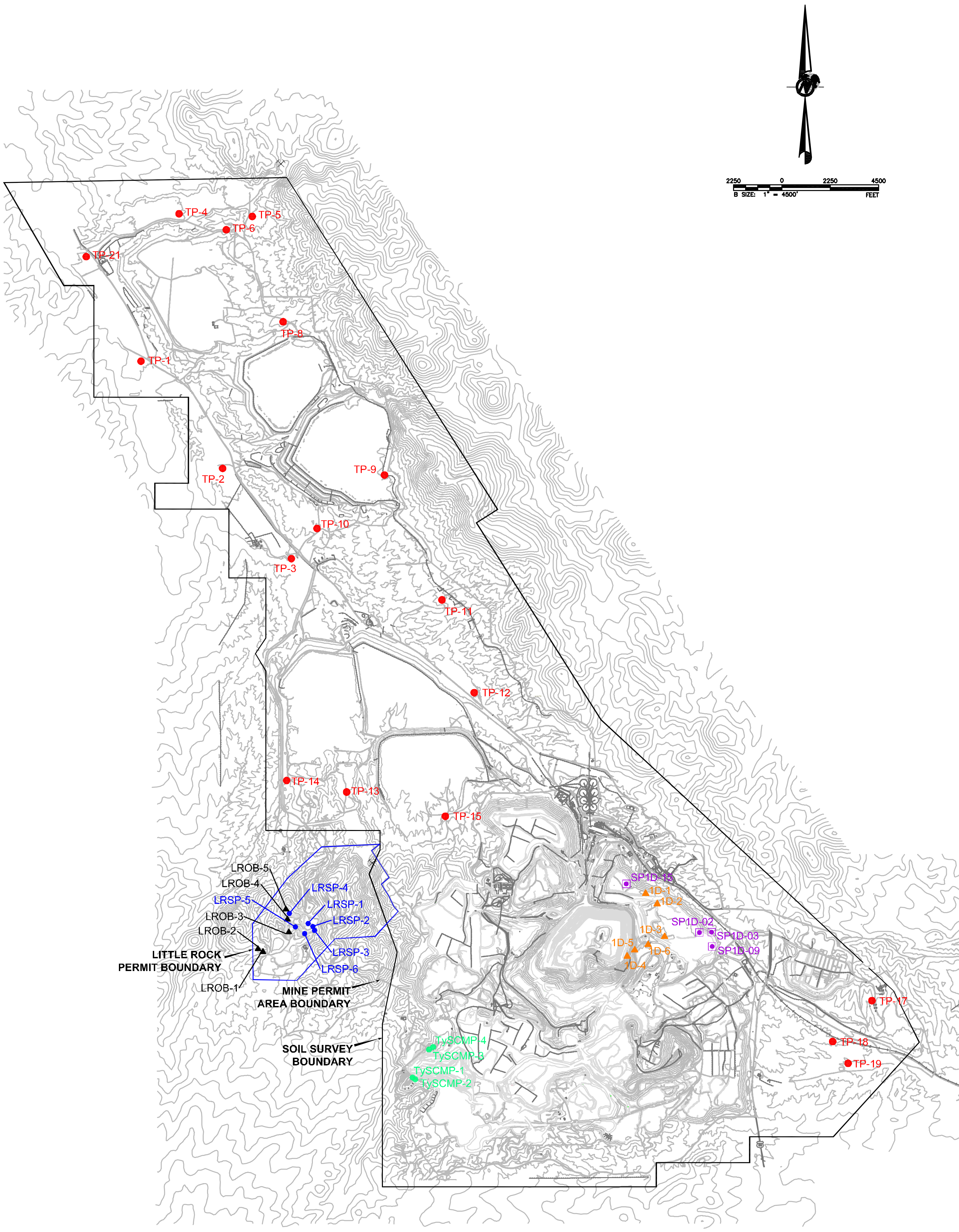
**TABLE B-18. MEASURED ROOT DENSITY DISTRIBUTION FOR RS5C**

| Soil Depth cm bgs | Column Identification | | | | | | | | | | Average roots/dm$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | |
| 0-10 | 86 | 67 | 75 | 38 | 46 | 70 | 66 | 72 | 63 | 100 | 68.3 |
| 10-20 | 12 | 17 | 30 | 28 | 12 | 10 | 38 | 42 | 49 | 16 | 25.4 |
| 20-30 | 6 | 14 | 17 | 22 | 17 | 27 | 31 | 30 | 35 | 18 | 21.7 |
| 30-40 | 5 | 7 | 9 | 10 | 12 | 14 | 16 | 25 | 14 | 21 | 13.3 |
| 40-50 | 7 | 4 | 16 | 6 | 13 | 5 | 10 | 11 | 8 | 14 | 9.4 |
| 50-60 | 5 | 3 | 6 | 4 | 6 | 7 | 14 | 5 | 1 | 16 | 6.7 |
| 60-70 | 10 | 5 | 2 | 8 | 14 | 8 | 8 | 6 | 6 | 9 | 7.6 |
| 70-80 | 4 | 3 | 2 | 6 | 8 | 9 | 3 | 5 | 7 | 8 | 5.5 |
| 80-90 | 0 | 0 | 3 | 1 | 5 | 4 | 2 | 2 | 8 | 3 | 2.8 |
| 90-100 | 5 | 0 | 1 | 4 | 2 | 5 | 10 | 1 | 2 | 5 | 3.5 |

Notes: each column of the grid was 10 cm in width
bgs = below ground surface
dm = decimeter

# APPENDIX C

# COVER MATERIAL CHARACTERIZATION DATA




| | |
|---|---|
| TySCMP-4 | TYRONE LEACH CAP |
| LROB-4 | LITTLE ROCK OVERBURDEN |
| LRSP-5 | LITTLE ROCK STOCKPILE |
| TP-15 | TEST PIT |
| 1D-3 | NO.1D STOCKPILE AND PIT WALL |
| SP1D-02 | NO.1D STOCKPILE |

PROJECT

phelps dodge TYRONE Inc.

PHELPS DODGE TYRONE INC.
GRANT COUNTY, NEW MEXICO

TITLE

# COVER MATERIAL SAMPLE LOCATIONS

Golder Associates
Albuquerque, New Mexico

| | | | | |
|---|---|---|---|---|
| PROJECT No. | | 043-2328 | FILE No. | 0432328 |
| DESIGN | LM | 01/25/05 | SCALE AS SHOWN | REV. A |
| CADD | CM | 01/25/05 | FIGURE C-1 | |
| CHECK | DR | 01/31/05 | | |
| REVIEW | -- | DATE | | |

K:\2004 Projects\043-2328 Tyr CCPE\Cover Material SampLoc.dwg

**Table C-1.**
**Chemical and Physical Properties of Selected Samples**
**from the Tyrone Mine (adapted from DBS&A, 1997c)**

| | | | Saturated Paste Extract | | | | | Hot Water Soluble | | | | Particles Size Distribution | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Horizon Designation /Layer** | **Depth[a]** *(in or ft)* | **Saturated Paste pH** | **EC** *(dS/m)* | **Calcium** *(meq/L)* | **Magnesium** *(meq/L)* | **Sodium** *(meq/L)* | **SAR** | **Selenium** *(mg/kg)* | **Boron** *(mg/kg)* | **$CaCO_3$ Equivalent** *% wt* | **Saturation Percent** *% water* | **Sand** *% wt* | **Silt** *% wt* | **Clay** *% wt* | **Rock Fragments** *% vol* | **USDA Texture Class[b]** |
| *Test Pit 1, Map Unit 10* | | | | | | | | | | | | | | | | |
| BW1 | 2-15" | 7.1 | 0.33 | 2.56 | 0.47 | 0.20 | 0.16 | <0.01 | 0.12 | 1.6 | 48.6 | 24 | 51 | 25 | 5 | SiL |
| BW2 | 15-52" | 7.6 | 1.66 | 18.00 | 2.22 | 1.02 | 0.32 | <0.01 | 0.12 | 2.4 | 46.1 | 28 | 56 | 16 | 7 | SiL |
| C | 52-62" | 7.7 | 0.99 | 8.99 | 1.21 | 0.96 | 0.43 | <0.01 | 0.08 | 2.5 | 25.9 | 66 | 27 | 7 | 55 | SL |
| Alluvium | 9-11' | 7.8 | 0.59 | 4.03 | 0.72 | 0.89 | 0.58 | <0.01 | 0.03 | 2.4 | 18.0 | 88 | 9 | 3 | 5 | S |
| Alluvium | 11-14' | 7.5 | 1.26 | 9.51 | 1.47 | 1.23 | 0.52 | <0.01 | 0.04 | 2.3 | 22.2 | 78 | 15 | 7 | 1 | LS |
| *Test Pit 2, Map Unit 10* | | | | | | | | | | | | | | | | |
| BW1 | 2-18" | 7.5 | 0.46 | 3.61 | 0.77 | 0.56 | 0.38 | <0.01 | 0.09 | 1.3 | 56.8 | 22 | 40 | 38 | 0 | CL |
| BW2 | 18-34" | 7.8 | 0.73 | 4.56 | 1.42 | 1.96 | 1.13 | <0.01 | 0.10 | 3.9 | 32.0 | 60 | 28 | 12 | 20 | SL |
| C | 34-57" | 7.8 | 1.56 | 11.40 | 3.23 | 4.40 | 1.63 | <0.01 | 0.13 | 2.5 | 21.7 | 88 | 9 | 3 | 45 | S |
| Alluvium | 4-13' | 7.7 | 1.45 | 11.20 | 1.84 | 1.86 | 0.73 | 0.02 | 0.04 | 2.2 | 22.8 | 71 | 22 | 7 | 5 | SL |
| *Test Pit 3, Map Unit 10* | | | | | | | | | | | | | | | | |
| A | 0-11" | 6.3 | 0.24 | 1.32 | 0.64 | 0.14 | 0.14 | <0.01 | 0.06 | 1.0 | 21.3 | 72 | 25 | 3 | 30 | SL |
| BW | 11-18" | 6.7 | 0.33 | 1.90 | 0.95 | 0.30 | 0.25 | <0.01 | 0.07 | 1.0 | 24.2 | 60 | 27 | 13 | 20 | SL |
| BC | 18-31" | 6.9 | 0.31 | 1.67 | 0.84 | 0.37 | 0.33 | <0.01 | 0.05 | 0.8 | 20.3 | 80 | 14 | 6 | 30 | LS |
| C | 31-58" | 7.2 | 0.26 | 1.28 | 0.65 | 0.30 | 0.31 | <0.01 | 0.06 | 1.1 | 15.6 | 84 | 11 | 5 | 45 | LS |
| Alluvium | 9-13' | 7.6 | 1.08 | 5.26 | 1.57 | 3.50 | 1.89 | 0.02 | 0.07 | 1.4 | 33.8 | 49 | 39 | 12 | 1 | L |
| *L* | | | | | | | | | | | | | | | | |
| A2 | 2-13" | 7.6 | 0.50 | 4.26 | 0.66 | 0.22 | 0.14 | <0.01 | 0.09 | 3.5 | 36.8 | 48 | 45 | 7 | 5 | L |
| BW | 13-30" | 7.7 | 0.47 | 3.73 | 0.65 | 0.61 | 0.41 | <0.01 | 0.11 | 3.9 | 29.7 | 58 | 37 | 5 | 5 | SL |
| C | 30-58" | 7.9 | 0.39 | 2.53 | 0.49 | 0.68 | 0.55 | <0.01 | 0.14 | 2.8 | 19.7 | 84 | 13 | 3 | 40 | LS |
| Alluvium | 2.5-14' | 7.9 | 0.58 | 3.71 | 0.83 | 1.20 | 0.80 | <0.01 | 0.10 | 3.3 | 20.2 | 82 | 14 | 4 | 5 | LS |
| *Test Pit 5, Map Unit 20* | | | | | | | | | | | | | | | | |
| A2 | 2-14" | 7.1 | 0.40 | 3.57 | 0.52 | 0.24 | 0.17 | <0.01 | 0.05 | 1.1 | 38.0 | 51 | 35 | 14 | 5 | L |
| BW | 14-26" | 7.6 | 0.39 | 3.21 | 0.46 | 0.29 | 0.21 | <0.01 | 0.06 | 6.0 | 29.4 | 64 | 29 | 7 | 22 | SL |
| C | 26-56" | 7.8 | 0.35 | 2.65 | 0.51 | 0.44 | 0.35 | <0.01 | 0.04 | 5.1 | 23.2 | 78 | 17 | 5 | 50 | LS |
| Alluvium | 5-7' | 7.8 | 0.34 | 2.04 | 0.55 | 0.93 | 0.82 | <0.01 | 0.05 | 4.2 | 21.7 | 80 | 15 | 5 | 10 | LS |
| Alluvium | 8-12' | 7.8 | 0.84 | 4.68 | 1.01 | 3.33 | 1.97 | <0.01 | 0.05 | 3.3 | 18.3 | 90 | 4 | 6 | 10 | S |
| *Test Pit 6, Map Unit 30* | | | | | | | | | | | | | | | | |
| Bt 1, Bt 2 | 2-20" | 6.7 | 0.44 | 2.69 | 1.14 | 0.59 | 0.43 | 0.01 | 0.13 | 0.9 | 40.0 | 60 | 15 | 25 | 55 | SCL |
| Bt 3 | 20-31" | 7.5 | 0.49 | 2.50 | 1.08 | 1.65 | 1.23 | <0.01 | 0.16 | 2.4 | 33.4 | 72 | 9 | 19 | 63 | SL |
| Bt 4 | 31-61" | 7.7 | 0.86 | 2.67 | 1.10 | 5.21 | 3.79 | <0.01 | 0.15 | 1.7 | 40.9 | 68 | 16 | 16 | 75 | SL |
| Bt 6 | 61-71" | 7.4 | 3.10 | 11.40 | 3.43 | 14.90 | 5.47 | <0.01 | 0.04 | 1.1 | 43.7 | 59 | 19 | 22 | 10 | SCL |
| Gila C | 6-8' | 7.4 | 3.74 | 14.80 | 3.94 | 17.80 | 5.82 | <0.01 | 0.02 | 1.7 | 44.1 | 48 | 47 | 5 | 0 | SL |
| Gila C | 8-10' | 7.6 | 2.62 | 9.92 | 2.22 | 11.90 | 4.83 | 0.01 | 0.02 | 2.9 | 27.4 | 75 | 19 | 6 | 5 | SL |
| Gila C | 10-14' | 7.7 | 2.00 | 7.81 | 1.61 | 8.54 | 3.94 | <0.01 | 0.01 | 2.1 | 18.8 | 85 | 11 | 4 | 55 | LS |
| Gila C | 14-20' | 7.6 | 0.98 | 6.13 | 0.88 | 2.52 | 1.35 | <0.01 | 0.02 | 3.4 | 21.1 | 82 | 13 | 5 | 15 | LS |
| *Test Pit 8, Map Unit 30* | | | | | | | | | | | | | | | | |
| Btk 1 | 2-17" | 7.4 | 0.56 | 2.37 | 0.80 | 3.02 | 2.40 | <0.01 | 0.13 | 1.2 | 75.2 | 27 | 20 | 53 | 15 | C |
| Btk 2 | 17-34" | 7.5 | 3.66 | 18.60 | 6.12 | 16.60 | 4.72 | 0.02 | 0.16 | 2.8 | 62.3 | 28 | 39 | 33 | 15 | CL |
| Btk 3 | 34-58" | 7.6 | 3.14 | 12.10 | 3.61 | 16.60 | 5.92 | <0.01 | 0.06 | 6.5 | 33.5 | 56 | 40 | 4 | 22 | SL |
| Btk 4 | 58-73" | 7.7 | 2.28 | 8.77 | 2.00 | 12.10 | 5.21 | <0.01 | 0.02 | 9.2 | 23.3 | 78 | 18 | 4 | 45 | LS |

**Table C-1.**
**Chemical and Physical Properties of Selected Samples from the Tyrone Mine (adapted from DBS&A, 1997c)**

| Horizon Designation /Layer | Depth[a] (in or ft) | Saturated Paste pH | Saturated Paste Extract: EC (dS/m) | Calcium (meq/L) | Magnesium (meq/L) | Sodium (meq/L) | SAR | Hot Water Soluble: Selenium (mg/kg) | Boron (mg/kg) | $CaCO_3$ Equivalent % wt | Saturation Percent % water | Particles Size Distribution: Sand % wt | Silt % wt | Clay % wt | Rock Fragments % vol | USDA Texture Class[b] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gila C | 4-12' | 7.6 | 1.92 | 9.87 | 1.72 | 7.00 | 2.90 | <0.01 | 0.01 | 4.1 | 24.5 | 72 | 21 | 7 | 65 | SL |
| Gila C | 12-14' | 7.6 | 1.20 | 7.10 | 1.21 | 2.53 | 1.24 | <0.01 | 0.01 | 1.7 | 32.6 | 60 | 29 | 11 | 15 | SL |
| Gila C | 14-20' | 7.6 | 1.00 | 6.11 | 1.16 | 1.68 | 0.88 | <0.01 | 0.01 | 1.5 | 25.4 | 70 | 17 | 13 | 50 | SL |
| *Test Pit 9, Map Unit 45* | | | | | | | | | | | | | | | | |
| A | 0-6" | 5.0 | 0.92 | 4.97 | 2.55 | 0.44 | 0.23 | <0.01 | 0.09 | 0.9 | 27.6 | 58 | 30 | 12 | 35 | SL |
| Bt 1 | 6-34" | 6.5 | 0.26 | 0.94 | 0.63 | 0.64 | 0.72 | <0.01 | 0.17 | 0.6 | 71.7 | 24 | 17 | 59 | 35 | C |
| Bt 2 | 34-70" | 7.6 | 2.65 | 8.57 | 6.08 | 14.50 | 5.36 | <0.01 | 0.15 | 6.0 | 47.2 | 60 | 15 | 25 | 65 | SCL |
| *0.07* | | | | | | | | | | | | | | | | |
| A, AB | 0-16" | 6.6 | 0.30 | 1.48 | 0.69 | 0.33 | 0.32 | <0.01 | 0.07 | 0.8 | 18.1 | 70 | 23 | 7 | 20 | SL |
| Bt 1, Bt 2 | 16-49" | 7.4 | 0.65 | 3.04 | 1.44 | 1.94 | 1.30 | <0.01 | 0.08 | 0.9 | 30.3 | 60 | 20 | 20 | 30 | SCL |
| Bt 3 | 49-63" | 7.8 | 1.01 | 2.47 | 1.68 | 5.98 | 4.15 | <0.01 | 0.08 | 1.9 | 34.4 | 48 | 35 | 17 | 7 | L |
| Gila C | 8-18' | 7.2 | 1.06 | 1.56 | 0.78 | 7.87 | 7.28 | <0.01 | 0.02 | 0.7 | 23.7 | 52 | 35 | 13 | 1 | L |
| Gila C | 18-20' | 6.8 | 0.70 | 0.91 | 0.48 | 5.14 | 6.17 | <0.01 | 0.01 | 0.7 | 16.4 | 84 | 8 | 8 | 10 | LS |
| *Test Pit 11, Map Unit 30* | | | | | | | | | | | | | | | | |
| A | 0-5" | 6.3 | 0.38 | 2.25 | 1.05 | 0.24 | 0.19 | <0.01 | 0.06 | 0.7 | 18.6 | 74 | 21 | 5 | 30 | SL |
| Bt 1 | 1-18" | 6.7 | 0.69 | 1.39 | 0.56 | 5.09 | 5.15 | <0.01 | 0.02 | 1.4 | 38.8 | 57 | 20 | 23 | 10 | SCL |
| Bt 2 | 18-60" | 6.8 | 0.92 | 1.78 | 0.73 | 6.21 | 5.54 | <0.01 | 0.01 | 1.7 | 35.5 | 62 | 23 | 15 | 25 | SL |
| Gila C | 16-20' | 6.6 | 0.70 | 2.33 | 0.99 | 3.17 | 2.46 | <0.01 | 0.02 | 1.1 | 37.8 | 54 | 25 | 21 | 5 | SCL |
| *Test Pit 12, Map Unit 20* | | | | | | | | | | | | | | | | |
| C | 2-54" | 7.5 | 0.36 | 2.81 | 0.57 | 0.23 | 0.18 | <0.01 | 0.02 | 0.7 | 17.0 | 82 | 12 | 6 | 50 | LS |
| Alluvium | 7-10' | 7.2 | 1.64 | 15.40 | 3.10 | 1.15 | 0.38 | <0.01 | 0.09 | 0.6 | 22.0 | 70 | 23 | 7 | <5 | SL |
| Alluvium | 10-15' | 7.4 | 0.59 | 4.08 | 1.04 | 0.53 | 0.33 | <0.01 | 0.03 | 0.5 | 18.4 | 88 | 6 | 6 | <5 | LS |
| *Test Pit 13, Map Unit 20* | | | | | | | | | | | | | | | | |
| A, C1 | 0-39" | 6.4 | 0.22 | 1.14 | 0.50 | 0.26 | 0.29 | <0.01 | 0.06 | 0.6 | 18.9 | 90 | 6 | 4 | 30 | S |
| C2 | 39-62" | 6.3 | 0.18 | 0.98 | 0.40 | 0.30 | 0.36 | <0.01 | 0.04 | 0.7 | 17.2 | 87 | 9 | 4 | 30 | LS |
| Alluvium | 6-14' | 6.8 | 0.23 | 1.37 | 0.84 | 0.47 | 0.45 | <0.01 | 0.04 | 0.4 | 20.2 | 94 | 3 | 3 | 20 | S |
| *Test Pit 14, Map Unit 40* | | | | | | | | | | | | | | | | |
| C1 | 0-46" | 6.9 | 0.43 | 0.50 | 0.24 | 3.80 | 6.25 | <0.01 | <0.01 | 0.9 | 22.9 | 76 | 13 | 11 | 46 | SL |
| C2 | 46-55" | 7.2 | 0.38 | 0.17 | 0.11 | 3.41 | 9.11 | <0.01 | <0.01 | 0.8 | 39.4 | 54 | 23 | 23 | 25 | SCL |
| *Test Pit 15, Map Unit 40* | | | | | | | | | | | | | | | | |
| A | 0-9" | 5.5 | 0.52 | 3.53 | 1.38 | 0.34 | 0.22 | 0.01 | 0.10 | 0.6 | 20.9 | 75 | 18 | 7 | 15 | SL |
| Bt 1 | 9-15" | 5.6 | 0.35 | 1.14 | 0.63 | 0.86 | 0.91 | <0.01 | 0.08 | 1.1 | 35.7 | 64 | 13 | 23 | 45 | SCL |
| Bt 2 | 15-46" | 7.4 | 0.71 | 1.71 | 0.72 | 4.54 | 4.12 | <0.01 | 0.08 | 1.1 | 22.6 | 72 | 20 | 8 | 50 | SL |
| C2 | 46-60" | 7.6 | 2.07 | 6.74 | 2.26 | 13.70 | 6.46 | <0.01 | 0.03 | 1.5 | 23.3 | 80 | 13 | 7 | 65 | LS |
| Gila C | 9-12.5" | 7.5 | 2.07 | 8.27 | 2.15 | 9.54 | 4.18 | <0.01 | 0.02 | 4.2 | 19.3 | 78 | 15 | 7 | 15 | LS |
| *Test Pit 17, Map Unit 40* | | | | | | | | | | | | | | | | |
| A | 0-11" | 5.2 | 0.42 | 1.97 | 0.90 | 0.24 | 0.20 | <0.01 | 0.09 | 0.7 | 18.5 | 66 | 28 | 6 | 17 | SL |
| Bt 1, Bt 2 | 11-29" | 5.8 | 0.28 | 1.36 | 0.64 | 0.63 | 0.63 | <0.01 | 0.11 | 1.2 | 24.4 | 71 | 15 | 14 | 50 | SL |
| BC | 29-60" | 7.5 | 0.42 | 2.17 | 0.90 | 1.32 | 1.07 | <0.01 | 0.01 | 0.7 | 22.4 | 80 | 10 | 10 | 65 | SL |
| *Test Pit 18, Map Unit 40* | | | | | | | | | | | | | | | | |
| A | 0-8" | 6.4 | 0.34 | 1.79 | 0.85 | 0.29 | 0.25 | <0.01 | 0.06 | 1.5 | 20.0 | 65 | 23 | 12 | 20 | SL |
| Bt 1 | 8-14" | 6.5 | 0.32 | 1.59 | 0.83 | 0.70 | 0.64 | <0.01 | 0.09 | 0.9 | 27.5 | 60 | 22 | 18 | 50 | SL |

**Table C-1.**
**Chemical and Physical Properties of Selected Samples from the Tyrone Mine (adapted from DBS&A, 1997c)**

| Horizon Designation /Layer | Depth[a] (in or ft) | Saturated Paste pH | Saturated Paste Extract: EC (dS/m) | Saturated Paste Extract: Calcium (meq/L) | Saturated Paste Extract: Magnesium (meq/L) | Saturated Paste Extract: Sodium (meq/L) | Saturated Paste Extract: SAR | Hot Water Soluble: Selenium (mg/kg) | Hot Water Soluble: Boron (mg/kg) | $CaCO_3$ Equivalent % wt | Saturation Percent % water | Particles Size Distribution: Sand % wt | Particles Size Distribution: Silt % wt | Particles Size Distribution: Clay % wt | Particles Size Distribution: Rock Fragments % vol | USDA Texture Class[b] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bt 2 | 14-24" | 6.5 | 0.56 | 0.95 | 0.45 | 1.75 | 2.09 | <0.01 | 0.20 | 0.4 | 51.1 | 42 | 14 | 44 | 40 | C |
| BC | 24-60" | 7.7 | 0.53 | 0.76 | 0.47 | 4.16 | 5.30 | <0.01 | 0.05 | 3.0 | 25.5 | 72 | 7 | 21 | 60 | SCL |
| *Test Pit 19, Map Unit 20* | | | | | | | | | | | | | | | | |
| A | 0-7" | 7.5 | 0.44 | 3.44 | 0.96 | 0.26 | 0.18 | <0.01 | 0.09 | 1.3 | 28.2 | 58 | 24 | 18 | 7 | SL |
| C1 | 7-43" | 7.5 | 0.24 | 1.51 | 0.54 | 0.33 | 0.33 | <0.01 | 0.04 | 1.1 | 20.8 | 88 | 5 | 7 | 32 | LS |
| C2 | 43-62" | 7.3 | 0.34 | 1.42 | 0.53 | 1.30 | 1.32 | <0.01 | 0.04 | 1.3 | 24.8 | 66 | 22 | 12 | 5 | SL |
| *Test Pit 21, Map Unit 10* | | | | | | | | | | | | | | | | |
| A, C1, C2 | 0-35" | 7.6 | 0.37 | 2.94 | 0.44 | 0.26 | 0.20 | <0.01 | 0.09 | 3.1 | 22.9 | 90 | 5 | 5 | 70 | S |
| C3 | 35-55" | 7.7 | 0.51 | 3.90 | 0.67 | 0.40 | 0.26 | 0.01 | 0.14 | 4.0 | 30.5 | 52 | 42 | 6 | 5 | SL |
| *Pit Wall Gila Conglomerate* | | | | | | | | | | | | | | | | |
| 1D-4 | Grab | 6.1 | 1.27 | 7.56 | 4.39 | 2.38 | 0.97 | <0.01 | 0.03 | 0.9 | 17.8 | 87 | 10 | 3 | 60 | S |
| 1D-5 | Grab | 6.2 | 0.94 | 6.43 | 2.36 | 1.47 | 0.70 | <0.01 | 0.04 | 0.9 | 19.4 | 84 | 11 | 5 | 40 | LS |
| 1D-6 | Grab | 6.7 | 1.96 | 15.00 | 6.06 | 4.43 | 1.37 | <0.01 | 0.03 | 1.2 | 19.5 | 84 | 12 | 4 | 15 | LS |
| *1D (5A) Stockpile* | | | | | | | | | | | | | | | | |
| 1D-1 | -- | *5.7* | *0.63* | *2.52* | *1.31* | *1.23* | *0.89* | *<0.01* | *0.05* | *0.8* | *20.8* | *79* | *13* | *8* | ND | *LS* |
| 1D-2 | -- | *5.1* | *0.75* | *4.67* | *2.29* | *0.51* | *0.27* | *<0.01* | *0.03* | *0.8* | *20.5* | *85* | *10* | *5* | ND | *LS* |
| 1D-3 | -- | *5.9* | *0.56* | *2.88* | *1.33* | *1.44* | *0.99* | *<0.01* | *0.03* | *1* | *21.3* | *84* | *11* | *5* | ND | *LS* |
| | | | | | | | | | | | | | | | | |
| SP1D-02 | -- | 5.7 | 1.17 | 7.61 | 3.97 | 1.86 | 0.77 | <0.01 | 0.02 | ND | 21.8 | 80 | 11 | 9 | ND | LS |
| SP1D-03 | -- | 6.5 | 0.16 | 2.39 | 1.24 | 1.07 | 0.79 | <0.01 | 0.02 | 0.4 | 23.2 | 80 | 12 | 8 | ND | LS |
| SP1D-09 | -- | 6.2 | 0.53 | 2.96 | 1.42 | 0.69 | 0.47 | <0.01 | 0.03 | BA | 18.5 | 86 | 7 | 7 | ND | LS |
| SP1D-15 | -- | 6.3 | 0.41 | 2.24 | 0.9 | 0.68 | 0.54 | <0.04 | 0.02 | NA | 19.1 | 82 | 10 | 8 | ND | LS |

[a] Depths for soil horizons are in inches; depths for the underlying geologic layers are in feet.

[b] USDA texture class according to Soil Survey Division Staff (1993)

**TABLE C-2**
**CHEMICAL AND PHYSICAL PROPERTIES OF SELECTED SAMPLES OF LITTLE ROCK AND TYRONE LEACHED CAP MATERIAL**

| Sample Identification | Depth[a] *(ft)* | Saturated Paste pH | Saturated Paste Extract: EC *(dS/m)* | Saturated Paste Extract: $NO_3$ *(mg/kg)* | $CaCO_3$ Equivalent *% wt* | Particles Size Distribution: Sand *% wt* | Silt *% wt* | Clay *% wt* | Rock Fragments *% vol* | USDA Texture Class[b] |
|---|---|---|---|---|---|---|---|---|---|---|
| *Little Rock Mine* | | | | | | | | | | |
| LRSP-1 | 0-0.5 | 5.7 | 0.12 | 1.9 | 0.9 | 65 | 19 | 16 | 59 | SL |
| LRSP-2 | 0-0.5 | 5.8 | 0.14 | 1.8 | 0.9 | 67 | 19 | 14 | 65 | SL |
| LRSP-3 | 0-0.5 | 7.1 | 0.25 | 2.5 | 1.1 | 72 | 16 | 12 | 64 | SL |
| LRSP-4 | 0-0.5 | 5.5 | 0.14 | 1.5 | 0.5 | 60 | 24 | 16 | 52 | SL |
| LRSP-5 | 0-0.5 | 5.7 | 0.12 | <1 | 0.9 | 70 | 16 | 14 | 46 | SL |
| LRSP-6 | 0-0.5 | 5.6 | 0.15 | 3 | 0.7 | 80 | 10 | 10 | 66 | *SL* |
| LROB-1 | 4-5 | 6.8 | 0.65 | <1 | 1.1 | 72 | 15 | 13 | 64 | SL |
| LROB-2 | 4-5 | 6.7 | 0.21 | <1 | 1 | 74 | 13 | 13 | 65 | SL |
| LROB-3 | 4-5 | 6.2 | 0.22 | <1 | 1 | 70 | 13 | 17 | 64 | SL |
| LROB-4 | 4-5 | 6.6 | 0.27 | <1 | 1.3 | 72 | 13 | 15 | 52 | SL |
| LROB-5 | 4-5 | 6 | 0.87 | 16 | 0.6 | 68 | 21 | 11 | 46 | *SL* |
| *Tyrone Leach Cap* | | | | | | | | | | |
| TySCMP-1 | -- | 6.7 | 0.36 | -- | <0.1 | 74 | 12 | 14 | 55 | SL |
| TySCMP-2 | -- | 6.1 | 0.29 | -- | <0.1 | 68 | 15 | 17 | 60 | SL |
| TyNCMP-1 | -- | 5.9 | 0.52 | -- | <0.1 | 66 | 18 | 16 | 65 | SL |
| TyNCMP-2 | -- | 4.9 | 0.68 | -- | <0.1 | 67 | 16 | 24 | 60 | SCL |

[a] Depths for soil horizons are in inches; depths for the underlying geologic layers are in feet.

[b] USDA texture class according to Soil Survey Division Staff (1993)

**Table C-3**
**Whole Rock Elemental Analytical Results for Mineral Assemblages 0 and 2**
**Assay Pulp Mineral Assemblage Samples (DBS&A, 1997)**

| Sample ID[a] | Concentration (mg/kg) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ag | Al | As | B | Ba | Be | Cd | Co | Cr | Cu | Fe | F | Mn | Mo | Ni | Pb | Se | V | Zn |
| *Mineral Assemblage 0* | | | | | | | | | | | | | | | | | | | |
| D43A-0-MA0 | 1.6 | 12300 | 28.7 | 12.1 | 265 | 0.5 | 1.07 | 6.6 | 31.6 | 697 | 19100 | 29.9 | 291 | 43.2 | 7.7 | 67.9 | 0.3 | 12.2 | 331 |
| D43A-100-MA0 | 0.5 | 8540 | 18.3 | 13.2 | 72.4 | 0.4 | ND | 2.9 | 34.6 | 421 | 10500 | 19.3 | 178 | 29.6 | 21.4 | 33 | 0.7 | 11.8 | 101 |
| D43A-150-MA0 | 0.6 | 7220 | 17.3 | 9.2 | 93.3 | 0.3 | ND | 5.4 | 25.3 | 930 | 12000 | 31.8 | 439 | 69.7 | 6.1 | 29.5 | ND | 7 | 130 |
| F44-140-MA0 | 0.6 | 11900 | 31.8 | 14.8 | 120 | 0.5 | 0.28 | 4 | 61.8 | 717 | 13500 | 17.3 | 258 | 47.8 | 9.8 | 36.2 | ND | 13.4 | 143 |
| F44-90-MAO | 0.6 | 7420 | 14.8 | 9.6 | 73.4 | 0.4 | 0.36 | 3.4 | 66.4 | 424 | 11500 | 16.1 | 183 | 23.2 | 11.6 | 23.5 | ND | 13.2 | 126 |
| GILA#1-MAO | 1.5 | 59300 | 60.7 | 12.2 | 112 | 1.8 | ND | 1.3 | 10.7 | 31.6 | 10100 | 15.3 | 172 | 2.9 | 4.1 | 27.1 | ND | 7.6 | 49.8 |
| GILA#2-MAO | ND | 6900 | 26.2 | 11.8 | 88.1 | 0.4 | ND | 2.8 | 23.4 | 194 | 10600 | 6.1 | 228 | 13.4 | 3.6 | 18.4 | 0.2 | 17.9 | 78 |
| GILA#3-MAO | 0.6 | 8410 | 16.9 | 8.8 | 63.1 | 0.8 | 0.45 | 4 | 33.8 | 289 | 13700 | 6.7 | 269 | 11.1 | 7.7 | 33.7 | ND | 19 | 111 |
| GILA#4MAO | 1.2 | 13000 | 21.4 | 10.9 | 79.1 | 0.8 | ND | 5.2 | 25.9 | 652 | 15200 | 11.7 | 274 | 12.5 | 5.3 | 30.2 | ND | 22.1 | 121 |
| GILA#5-MAO | 1.3 | 8930 | 27.4 | 13.3 | 83.4 | 0.7 | 0.51 | 2.8 | 32.3 | 333 | 17500 | 8.7 | 163 | 40.2 | 8.4 | 33.3 | ND | 21.3 | 115 |
| GILA#6-MAO | 0.7 | 7070 | 17.1 | 11.1 | 77.3 | 0.5 | 0.37 | 2.2 | 22.9 | 254 | 13800 | 8.1 | 150 | 22.7 | 6.9 | 30.9 | ND | 16.7 | 100 |
| DE43A-50-MAO | ND | 8620 | ND | 21.2 | 88 | 0.3 | ND | 3.1 | 42 | 314 | 14100 | 17.8 | ND | 32 | 11.7 | 35.6 | ND | 17.6 | 81 |
| *Mineral Assemblage 1* | | | | | | | | | | | | | | | | | | | |
| AD33-451-MA1 | 0.5 | 10700 | 31.7 | 5.1 | 260 | 0.8 | 0.85 | 9.2 | 3.3 | 549 | 16200 | 8.2 | 1970 | 2.2 | 8.8 | 52.6 | ND | 4.2 | 782 |
| AG34-684-MA-1 | 3.0 | 5190 | 8.7 | ND | 133 | 0.5 | 14 | 9.1 | 34.9 | 631 | 16200 | 20.2 | 325 | 16.2 | 8.2 | 566 | 0.8 | 2.7 | 2430 |
| BE38-148-MA1 | 0.4 | 9570 | 22 | 7 | 49.5 | 0.4 | ND | 0.7 | 41.1 | 321 | 9070 | 7.3 | 20.8 | 210 | 4.3 | 42.8 | 1.2 | 6.6 | 12.2 |
| BE38-98-MA1 | 0.6 | 8930 | 14 | 5.3 | 46.3 | 0.3 | ND | 1.6 | 29.2 | 182 | 6900 | 8.9 | 26.2 | 110 | 2.2 | 167 | 0.5 | 7.8 | 13.9 |
| BH26-172-MA1 | 3.0 | 6720 | ND | ND | 109 | 0.2 | 0.41 | 0.8 | 49.9 | 807 | 20600 | 7.1 | 124 | 138 | 4.8 | 354 | ND | 9.8 | 176 |
| BJ40-237-MA1 | 0.7 | 10700 | 19.9 | 9.3 | 109 | 0.5 | 0.73 | 1.5 | 63.1 | 504 | 12800 | 4.9 | 69 | 151 | 10.7 | 54 | 0.2 | 16.8 | 100 |
| BJ40-287-MA1 | ND | 6460 | 22.3 | 6.2 | 54 | 0.3 | 1.12 | 1.5 | 56.9 | 455 | 6500 | 4.2 | 58.4 | 74.6 | 10.8 | 12.5 | 0.3 | 7.7 | 89.9 |
| M50-294-MA1 | 0.4 | 7730 | ND | ND | 136 | 0.1 | ND | 1.4 | 69.1 | 241 | 22900 | 3.1 | 52.7 | 11.5 | ND | 27.3 | 0.4 | 6.6 | 55.1 |
| O50-700-MA1 | 1.7 | 13200 | 32.2 | 5.7 | 242 | 0.7 | ND | 12.2 | 3.8 | 576 | 28200 | 5.6 | 1530 | 48.8 | ND | 15.6 | 0.3 | 4.1 | 186 |
| AL18-253-MA1 | ND | 14800 | ND | 19.6 | 208 | 0.4 | ND | 4 | 48.1 | 76.7 | 13100 | 4.4 | ND | 5.9 | 4.6 | 26.1 | 0.3 | 10.5 | 92.4 |
| BB25-44-MA1 | 1.2 | 7580 | ND | 34.8 | 191 | ND | ND | 0.6 | 6.2 | 327 | 28000 | ND | ND | 382 | 4.3 | 41.7 | 0.6 | 11.3 | 23.8 |
| E10-0-MA1 | 3.2 | 5980 | ND | 44 | 470 | ND | ND | 1.4 | 8.6 | 365 | 36200 | ND | ND | 55.4 | 18.2 | 56.1 | ND | 8.7 | 40.8 |
| F17-0-MA1 | 1.8 | 5980 | ND | 17 | 182 | ND | ND | ND | ND | 162 | 11200 | 5.3 | ND | 73.8 | ND | 48.7 | 0.8 | 2.3 | 15.7 |
| F17-108-MA1 | ND | 2180 | ND | 11.4 | 68.6 | ND | ND | 0.5 | ND | 244 | 6720 | 4.8 | 24.2 | 58.8 | ND | 61.2 | 0.7 | 1.6 | 22.2 |
| F17-58-MA1 | ND | 1340 | ND | 9.9 | 73.6 | ND | ND | 0.6 | ND | 186 | 6040 | 3.9 | 7.6 | 55.6 | ND | 49.4 | ND | 2.3 | 24.2 |
| G50-627-MA1 | ND | 10200 | ND | 18.3 | 150 | 0.3 | ND | ND | 130 | 226 | 15700 | 3.1 | 40.7 | 50.3 | 2.1 | 10.3 | 0.4 | 5.8 | 21.5 |
| G50-677-MA1 | ND | 12800 | ND | 18.3 | 142 | 0.4 | ND | 0.6 | 173 | 218 | 17400 | 5.9 | 83 | 35.7 | ND | 23.4 | 0.2 | 6.9 | 31.8 |
| G50-777-MA1 | 1.1 | 15200 | ND | 28.7 | 199 | 0.7 | ND | 1.2 | 83.5 | 624 | 25500 | 16.4 | 61.8 | 37.9 | ND | 31.5 | ND | 9.3 | 61.5 |
| M50-434-MA1 | 0.9 | 10600 | ND | 16.5 | 141 | 0.7 | ND | 6.2 | 56.5 | 984 | 13600 | 19.7 | 436 | 18.7 | ND | 86.6 | 0.6 | 7 | 288 |

Notes:

[a] Combination of assay pulp samples analyzed during PMC and SMC

**Table C-4.**
**Acid-Base Account and Sulfur Forms Data from the**
**Supplemental Materials Characterization Tyrone Mine Closure/Closeout (DBS&A, 1997)**

| Sample ID[a] | | | | Sulfur Content (wt %) | | | |
|---|---|---|---|---|---|---|---|
| | ABA[b] | AGP[c] | ANP[d] | Residual | Pyritic | Sulfate | Total |
| *Mineral Assemblage 0* | | | | | | | |
| D43A-0-MA0 | -13.7 | | 7.5 | 0.01 | 0.68 | 0.11 | 0.8 |
| D43A-100-MA0 | 9.7 | 0.31 | 10 | ND | 0.01 | 0.03 | 0.04 |
| D43A-150-MA0 | 6.9 | 0.31 | 7.2 | ND | 0.01 | 0.04 | 0.05 |
| F44-140-MA0 | 19.5 | 0.31 | 19.8 | ND | 0.01 | 0.05 | 0.06 |
| F44-90-MAO | 15.1 | 0.31 | 15.4 | ND | 0.01 | 0.02 | 0.03 |
| GILA#1-MAO | 29.5 | ND | 29.5 | ND | ND | ND | 0.01 |
| GILA#2-MAO | 11.8 | ND | 11.8 | 0.02 | ND | ND | 0.02 |
| GILA#3-MAO | 14.1 | ND | 14.1 | ND | ND | 0.09 | 0.09 |
| GILA#4MAO | 6 | 0.31 | 6.3 | ND | 0.01 | 0.22 | 0.23 |
| GILA#5-MAO | 12.6 | 0.31 | 12.9 | ND | 0.01 | 0.03 | 0.04 |
| GILA#6-MAO | 6.9 | 0.31 | 7.2 | ND | 0.01 | 0.05 | 0.06 |
| D43A-50-MAO | 5.6 | ND | 5.6 | ND | ND | 0.03 | 0.04 |
| 1D-1 | 8 | <1 | 8 | nt | nt | nt | 0.03 |
| 1D-2 | 8 | <1 | 8 | nt | nt | nt | 0.03 |
| 1D-3 | 10 | <1 | 10 | nt | nt | nt | 0.03 |
| 1D-4[e] | 9 | <1 | 9 | nt | nt | nt | 0.03 |
| 1D-5[e] | 9 | <1 | 9 | nt | nt | nt | 0.03 |
| 1D-6[e] | 12 | <1 | 12 | nt | nt | nt | 0.02 |
| SP1D-02 | 2 | <1 | 2 | <0.01 | 0.01 | 0.03 | 0.05 |
| SP1D-03 | 3 | 1 | 4 | <0.01 | 0.02 | 0.01 | 0.03 |
| SP1D-07 | -2 | 5 | 3 | 0.01 | 0.16 | 0.16 | 0.33 |
| SP1D-09 | 6 | <1 | 6 | <0.01 | <0.01 | 0.01 | 0.02 |
| SP1D-11 | 1 | 3 | 4 | 0.08 | 0.08 | 0.05 | 0.21 |
| SP1D-15 | 3 | <1 | 3 | <0.01 | <0.01 | 0.03 | 0.04 |
| *Mineral Assemblage 1* | | | | | | | |
| AD33-451-MA1 | 14.8 | 0.31 | 15.1 | ND | 0.01 | 0.03 | 0.04 |
| AG34-684-MA-1 | -38.9 | 55.6 | 16.8 | 0.03 | 1.78 | 0.24 | 2.05 |
| BE38-148-MA1 | 5.5 | 0.63 | 6.2 | ND | 0.02 | 0.09 | 0.12 |
| BE38-98-MA1 | 7.7 | 0.63 | 8.3 | 0.01 | 0.02 | 0.08 | 0.11 |
| BH26-172-MA1 | 14.6 | 7.19 | 21.7 | 0.02 | 0.23 | 0.1 | 0.35 |
| BJ40-237-MA1 | 7.3 | 2.81 | 10.1 | ND | 0.09 | 0.14 | 0.23 |
| BJ40-287-MA1 | 5.1 | 0.31 | 5.4 | ND | 0.01 | 0.07 | 0.08 |
| M50-294-MA1 | 2.5 | 12.5 | 15 | 0.34 | 0.4 | 0.22 | 0.96 |
| O50-700-MA1 | -9.7 | 19.7 | 10 | 0.84 | 0.63 | 0.18 | 1.65 |
| AL18-253-MA1 | 23.7 | ND | 23.7 | ND | ND | ND | 0.01 |
| BB25-44-MA1 | -4 | 10.6 | 6.6 | 0.32 | 0.34 | 0.05 | 0.71 |
| E10-0-MA1 | -14.2 | 18.6 | 4.6 | ND | 0.6 | 0.11 | 0.72 |
| F17-0-MA1 | -4.8 | 5.3 | 0.5 | 0.01 | 0.17 | 0.06 | 0.24 |
| F17-108-MA1 | -1.3 | 1.3 | ND | ND | 0.04 | 0.06 | 0.11 |
| F17-58-MA1 | -5.9 | 5.9 | ND | 0.04 | 0.19 | 0.08 | 0.31 |
| G50-627-MA1 | -16.6 | 20.3 | 3.7 | 0.07 | 0.65 | 0.05 | 0.77 |
| G50-677-MA1 | -4.5 | 8.1 | 3.6 | 0.02 | 0.26 | 0.11 | 0.39 |
| G50-777-MA1 | -14 | 16.6 | 2.6 | 0.01 | 0.53 | 0.12 | 0.66 |
| M50-434-MA1 | 4.2 | 1.6 | 5.8 | 0.04 | 0.05 | 0.1 | 0.19 |

Notes:

[a] Combination of assay pulp samples analyzed during PMC and SMC

[b] ABA = Acid-base account = ANP - AGP, in tons $CaCO^3$ per 1,000 tons or rock

[c] AGP = Acid-generation potential, in tons $CaCO^3$ per 1,000 tons of rock

[d] ANP = Acid-neutralization potential, in ton $CaCO^3$ per 1,000 tons of rock

[e] = Grab sample obtained from pit wall of the Main Pit

ND = non-detect

nt = not tested

# APPENDIX D

# UNSAT-H INPUT PARAMETERS AND ANNUAL OUTPUT SUMMARIES

**TABLE D-1**
**COVER MODELING INPUT PARAMETERS FOR**
**CONDITION 75: COMPREHENSIVE COVER PERFORMANCE EVALUATION.**

| Input Parameter | Model Variable | Values | Units | Comments |
|---|---|---|---|---|
| **Climate** | | | | |
| Precipitation | -- | 102 years of daily data, | in/day | Ft. Bayard period of record; first 2 years set initial soil-water conditions |
| Temperature | -- | 102 years of daily data | ˚F | Ft. Bayard period of record |
| Dewpoint | -- | 9.8-22.7 | ˚F | Monthly average calculated from average temperature and relative humidity (RH). |
| Solar radiation | -- | 400-900 | langleys | Calculated from latitude and date (Barbour et al., 1987) |
| Wind speed | -- | 8.3-12.7 | mi/hr | Monthly average for Deming, NM. |
| Cloud cover | -- | 3.4-5.1 | tenths | Monthly average for Albuquerque, NM |
| **Vegetation** | | | | |
| Leaf area index | NDLAI, IDLAI, VLAI | 0.012 to 0.29 | none | Functional relationship with a maximum of 0.29 (see Section 2) |
| Rooting growth and density | AA, B1, B2 | 7.0E-01, 6.0E-02, 1.6E-02 | none | Functional relationship with a 69-20-7-4 quartile root distribution; RLD = $a$ exp(-$bz$) + $c$ (see Section 3) |
| Growth day roots are at model node | NTROOT | 1 – cover<br>366 – stockpile | | Assumes perennial vegetation and roots restricted to cover: 1 – roots always at node, 366 – no roots at node for stockpile |
| Water uptake | NUPTAK | Sink term | | Feddes et al., 1978 |
| PET partitioning | NFPET | calculated | | Program partitions based on LAI and equation by Ritchie and Burnett (1971) |
| PET partitioning coefficients | PETPC | 0.0, 0.52, 0.5, 0.0, 2.7 | | Coefficients of Ritchie equation (= $a + b\text{LAI}^c$) |
| Head | | | | |
| • Wilting point | HW | 2.0E+04 | cm | Head below which plant wilt and stop transpiring |
| • Dry conditions | HD | 3.0E+03 | cm | Head below which plant decrease transpiration |
| • Anaerobic | HN | 1.0E+0 | cm | Head above which transpiration stops due to anaerobic conditions |

**TABLE D-1**
**COVER MODELING INPUT PARAMETERS FOR**
**CONDITION 75: COMPREHENSIVE COVER PERFORMANCE EVALUATION (CON'T).**

| Input Parameter | Model Variable | Values | Units | Comments |
|---|---|---|---|---|
| **Soil** | | | | |
| $K_{sat}$ | SK | 15.12 – cover (TP3 1-9')[a]<br>36.0 – stockpile<br>0.0018 – tailing | cm/hr | measured (DBS&A, 1999) |
| Saturated water content | THET | 0.3120 – cover (TP3 1-9') [a]<br>0.140 – stockpile<br>0.430 – tailing | $cm^3$/ $cm^3$ | measured (DBS&A, 1999) |
| Residual water content | THTR | 0.0350 – cover (TP3 1-9') [a]<br>0.0 – stockpile<br>0.01 – tailing | $cm^3$/ $cm^3$ | measured (DBS&A, 1999) |
| $\alpha$ | VGA | 0.0316– cover (TP3 1-9')<br>0.0425 – stockpile<br>0.0010 – tailing | $cm^{-1}$ | Van Genuchten coefficient for material (DBS&A, 1999) |
| $n$ | VGN | 1.4480 – cover (TP3 1-9')<br>1.2134 – stockpile<br>1.6517 – tailing | none | Van Genuchten coefficient for material (DBS&A, 1999) |
| Conductivity model | RKMOD | | | Mualem ($m$ = 1-1/$n$) |
| Cover thickness | -- | 60, 90, 120, 150 | cm | 3 cover depths for stockpile, 4 cover depths for tailing |
| Lower boundary domain | -- | variable | cm | 10 m below cover |

[a] modified to account for increased rock fragments

**TABLE D-1**
**COVER MODELING INPUT PARAMETERS FOR**
**CONDITION 75: COMPREHENSIVE COVER PERFORMANCE EVALUATION (CON'T).**

| Input Parameter | Model Variable | Values | Units | Comments |
|---|---|---|---|---|
| **Other Model Variables** | | | | |
| Surface boundary condition | ITOPBC | flux | none | |
| Upper boundary– heat flow | UPPERH | calculated | | based on weather and soil parameters |
| Surface evaporation | IEVOPT | allow | | |
| PET distribution | NFHOUR | hourly | | sine wave function from 6am to 6pm |
| Lower boundary condition | LOWER | unit gradient | none | |
| Lower boundary– heat flow | LOWERH | none | none | |
| Minimum head –wet | HIRRI | 0 | cm | |
| Maximum head – dry | HDRY | 1.0 $e^6$ | cm | |
| Constant head at surface | HTOP | 0 | cm | |
| Vapor flow | IVAPOR | allowed | | |
| Tortuousity | TORT | 0.66 | | |
| Vapor diffusion coefficient | VAPDIF | 0.24 | $cm^2/s$ | |
| PET | ALBEDO | 0.35 | cm/day | |
| Altitude | ALT | 1872.1 | m | |
| Height of wind measure | ZU | 6.1 | m | |
| Average atmospheric pressure | PMB | 838.4 | mb | |

**TABLE D-2**
**SUMMARY OF SIMULATED DRAINAGE (100 YEARS) FOR STOCKPILE AND TAILING COVERS TYRONE MINE CCPE.**

| Year | Stockpile Covers | | | | | Tailing Covers | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 60 | 60HL[a] | 90 | 120 | | 45 | 60 | 60HL | 90 | 120 |
| | cm | | | | | cm | | | | |
| 1899 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.02 | 0.01 | 0.01 | < 0.01 | < 0.01 |
| 1900 | 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.04 | 0.02 | 0.01 | < 0.01 | < 0.01 |
| 1901 | 0.04 | 0.03 | < 0.01 | 0.03 | | 0.05 | 0.02 | 0.01 | < 0.01 | < 0.01 |
| 1902 | 0.55 | 0.41 | 0.02 | 0.41 | | 0.06 | 0.02 | 0.01 | < 0.01 | < 0.01 |
| 1903 | 0.57 | 0.50 | 0.18 | 0.50 | | 0.08 | 0.03 | 0.01 | < 0.01 | < 0.01 |
| 1904 | 4.68 | 4.21 | 3.31 | 4.21 | | 0.17 | 0.08 | 0.03 | < 0.01 | < 0.01 |
| 1905 | 3.27 | 3.15 | 3.15 | 3.15 | | 1.56 | 1.10 | 0.71 | 1.39 | 2.21 |
| 1906 | 0.22 | 0.18 | 0 | 0.18 | | 1.78 | 1.54 | 1.32 | 1.21 | 0.74 |
| 1907 | 0.91 | 0.94 | 0.79 | 0.94 | | 1.62 | 1.38 | 1.20 | 0.96 | 0.49 |
| 1908 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 1.04 | 0.93 | 0.86 | 0.60 | 0.23 |
| 1909 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.59 | 0.52 | 0.49 | 0.28 | 0.04 |
| 1910 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.34 | 0.29 | 0.28 | 0.14 | < 0.01 |
| 1911 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.21 | 0.17 | 0.17 | 0.06 | < 0.01 |
| 1912 | 0.28 | 0.18 | < 0.01 | 0.18 | | 0.23 | 0.15 | 0.12 | 0.02 | < 0.01 |
| 1913 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.32 | 0.20 | 0.13 | 0.02 | < 0.01 |
| 1914 | 0.68 | 0.43 | < 0.01 | 0.43 | | 0.28 | 0.17 | 0.11 | < 0.01 | < 0.01 |
| 1915 | 2.01 | 1.84 | 1.40 | 1.84 | | 1.03 | 0.62 | 0.37 | 0.12 | < 0.01 |
| 1916 | 0.14 | < 0.01 | < 0.01 | < 0.01 | | 1.03 | 0.77 | 0.59 | 0.30 | 0.10 |
| 1917 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.89 | 0.63 | 0.45 | 0.16 | < 0.01 |
| 1918 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.52 | 0.41 | 0.32 | 0.09 | < 0.01 |
| 1919 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.33 | 0.24 | 0.19 | 0.03 | < 0.01 |
| 1920 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.31 | 0.18 | 0.13 | < 0.01 | < 0.01 |
| 1921 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.22 | 0.12 | 0.08 | < 0.01 | < 0.01 |
| 1922 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.11 | 0.06 | 0.04 | < 0.01 | < 0.01 |
| 1923 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.06 | 0.02 | 0.01 | < 0.01 | < 0.01 |
| 1924 | 0.03 | < 0.01 | < 0.01 | < 0.01 | | 0.11 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| 1925 | 1.73 | 1.52 | 1.25 | 1.52 | | 0.13 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| 1926 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.41 | 0.21 | 0.10 | 0.10 | 0.04 |
| 1927 | 0.63 | 0.24 | < 0.01 | 0.24 | | 0.54 | 0.32 | 0.20 | 0.17 | 0.06 |
| 1928 | 0.41 | 0.19 | 0.01 | 0.19 | | 0.69 | 0.42 | 0.22 | 0.13 | < 0.01 |
| 1929 | 0.39 | 0.27 | 0.11 | 0.27 | | 0.76 | 0.49 | 0.25 | 0.11 | < 0.01 |
| 1930 | 0.33 | 0.11 | < 0.01 | 0.11 | | 0.70 | 0.51 | 0.27 | 0.11 | < 0.01 |
| 1931 | 0.07 | 0.05 | < 0.01 | 0.05 | | 0.82 | 0.57 | 0.28 | 0.09 | < 0.01 |
| 1932 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.58 | 0.44 | 0.27 | 0.08 | < 0.01 |
| 1933 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.27 | 0.22 | 0.16 | 0.03 | < 0.01 |
| 1934 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.12 | 0.10 | 0.08 | < 0.01 | < 0.01 |
| 1935 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.12 | 0.06 | 0.04 | < 0.01 | < 0.01 |
| 1936 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.13 | 0.06 | 0.03 | < 0.01 | < 0.01 |
| 1937 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.10 | 0.04 | 0.02 | < 0.01 | < 0.01 |
| 1938 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.03 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1939 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.03 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1940 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.06 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |

**TABLE D-2**
**SUMMARY OF SIMULATED DRAINAGE (100 YEARS) FOR**
**STOCKPILE AND TAILING COVERS TYRONE MINE CCPE (CON T).**

| Year | Stockpile Covers | | | | | Tailing Covers | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 60 | 60HL[a] | 90 | 120 | | 45 | 60 | 60HL | 90 | 120 |
| | cm | | | | | cm | | | | |
| 1941 | 0.58 | 0.50 | 0.06 | 0.50 | | 0.09 | 0 | 0 | < 0.01 | < 0.01 |
| 1942 | 0.06 | 0.01 | < 0.01 | 0.01 | | 0.26 | 0.06 | 0.02 | < 0.01 | < 0.01 |
| 1943 | 0.05 | < 0.01 | < 0.01 | < 0.01 | | 0.25 | 0.09 | 0.04 | < 0.01 | < 0.01 |
| 1944 | 0.79 | 0.59 | 0.17 | 0.59 | | 0.24 | 0.08 | 0.04 | < 0.01 | < 0.01 |
| 1945 | < 0.01 | < 0.01 | 0.11 | < 0.01 | | 0.45 | 0.20 | 0.09 | < 0.01 | < 0.01 |
| 1946 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.36 | 0.22 | 0.13 | < 0.01 | < 0.01 |
| 1947 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.18 | 0.13 | 0.09 | < 0.01 | < 0.01 |
| 1948 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.08 | 0.05 | 0.04 | < 0.01 | < 0.01 |
| 1949 | 1.04 | 0.95 | 0.38 | 0.95 | | 0.16 | 0.06 | 0.03 | < 0.01 | < 0.01 |
| 1950 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.33 | 0.18 | 0.12 | < 0.01 | < 0.01 |
| 1951 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.20 | 0.14 | 0.11 | < 0.01 | < 0.01 |
| 1952 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.07 | 0.06 | 0.06 | < 0.01 | < 0.01 |
| 1953 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.01 | 0.01 | 0.02 | < 0.01 | < 0.01 |
| 1954 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1955 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1956 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1957 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1958 | 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1959 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1960 | 0.34 | 0.23 | < 0.01 | 0.23 | | 0.04 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1961 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.13 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1962 | 0.19 | 0.15 | < 0.01 | 0.15 | | 0.12 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1963 | < 0.01 | 0.01 | < 0.01 | 0.01 | | 0.16 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| 1964 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.14 | 0.04 | < 0.01 | < 0.01 | < 0.01 |
| 1965 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.09 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| 1966 | 0.69 | 0.50 | < 0.01 | 0.50 | | 0.10 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| 1967 | 0.17 | 0.14 | 0.01 | 0.14 | | 0.26 | 0.07 | 0.01 | < 0.01 | < 0.01 |
| 1968 | 0.60 | 0.46 | < 0.01 | 0.46 | | 0.37 | 0.16 | 0.06 | < 0.01 | < 0.01 |
| 1969 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.47 | 0.24 | 0.12 | < 0.01 | < 0.01 |
| 1970 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.29 | 0.19 | 0.12 | < 0.01 | < 0.01 |
| 1971 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.14 | 0.10 | 0.08 | < 0.01 | < 0.01 |
| 1972 | 2.22 | 1.61 | 0.92 | 1.61 | | 0.09 | 0.05 | 0.04 | < 0.01 | < 0.01 |
| 1973 | 0.21 | 0.25 | 0.55 | 0.25 | | 0.66 | 0.36 | 0.15 | < 0.01 | < 0.01 |
| 1974 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.60 | 0.48 | 0.30 | 0.07 | 0.01 |
| 1975 | 0.81 | 0.62 | 0.16 | 0.62 | | 0.33 | 0.28 | 0.21 | 0.08 | 0.02 |
| 1976 | < 0.01 | < 0.01 | 0.08 | < 0.01 | | 0.58 | 0.38 | 0.23 | 0.07 | < 0.01 |
| 1977 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.35 | 0.30 | 0.23 | 0.08 | < 0.01 |
| 1978 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.14 | 0.15 | 0.14 | 0.05 | < 0.01 |
| 1979 | 0.98 | 0.96 | 0.54 | 0.96 | | 0.23 | 0.15 | 0.11 | 0.03 | < 0.01 |
| 1980 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.31 | 0.23 | 0.19 | 0.07 | < 0.01 |

**TABLE D-2**
**SUMMARY OF SIMULATED DRAINAGE (100 YEARS) FOR STOCKPILE AND TAILING COVERS TYRONE MINE CCPE (CON T).**

| Year | Stockpile Covers | | | | | Tailing Covers | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 60 | 60HL[a] | 90 | 120 | | 45 | 60 | 60HL | 90 | 120 |
| | cm | | | | | cm | | | | |
| 1981 | 0.34 | 0.20 | < 0.01 | 0.20 | | 0.16 | 0.13 | 0.13 | 0.06 | < 0.01 |
| 1982 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.26 | 0.16 | 0.12 | 0.03 | < 0.01 |
| 1983 | 1.07 | 0.85 | 0.26 | 0.85 | | 0.20 | 0.14 | 0.11 | 0.02 | < 0.01 |
| 1984 | 0 | 0.05 | 0.36 | 0.05 | | 0.52 | 0.29 | 0.18 | 0.02 | < 0.01 |
| 1985 | 0.68 | 0.58 | 0.07 | 0.58 | | 0.51 | 0.36 | 0.26 | 0.08 | < 0.01 |
| 1986 | 1.68 | 1.13 | 0.54 | 1.13 | | 0.58 | 0.41 | 0.30 | 0.10 | < 0.01 |
| 1987 | 0.41 | 0.50 | 0.74 | 0.50 | | 1.37 | 0.94 | 0.55 | 0.20 | < 0.01 |
| 1988 | 0.45 | 0.21 | < 0.01 | 0.21 | | 0.90 | 0.78 | 0.59 | 0.31 | 0.07 |
| 1989 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.77 | 0.68 | 0.48 | 0.22 | 0.05 |
| 1990 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.29 | 0.31 | 0.28 | 0.15 | 0.01 |
| 1991 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.11 | 0.13 | 0.14 | 0.08 | < 0.01 |
| 1992 | 0.14 | 0.15 | < 0.01 | 0.15 | | 0.25 | 0.15 | 0.12 | 0.03 | < 0.01 |
| 1993 | 1.00 | 1.03 | 0.63 | 1.03 | | 0.54 | 0.35 | 0.24 | 0.04 | < 0.01 |
| 1994 | 0.68 | 0.67 | 0.04 | 0.67 | | 0.38 | 0.35 | 0.32 | 0.11 | < 0.01 |
| 1995 | 1.71 | 1.72 | 1.22 | 1.72 | | 0.67 | 0.55 | 0.46 | 0.19 | < 0.01 |
| 1996 | 0.83 | 0.60 | 0.80 | 0.60 | | 1.29 | 1.14 | 0.99 | 0.56 | 0.13 |
| 1997 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.94 | 0.87 | 0.77 | 0.49 | 0.18 |
| 1998 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | 0.31 | 0.34 | 0.34 | 0.24 | 0.09 |
| Average | 0.35 | 0.29 | 0.18 | 0.29 | | 0.37 | 0.26 | 0.19 | 0.10 | 0.04 |

[a] high leaf area (peak LAI = 0.42)

**TABLE D-3**
**SUMMARY OF SIMULATED RUNOFF (100 YEARS) FOR STOCKPILE AND TAILING COVERS TYRONE MINE CCPE.**

| Year | Stockpile Covers | | | | | Tailing Covers | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 60 | 60HL[a] | 90 | 120 | | 45 | 60 | 60HL | 90 | 120 |
| | cm | | | | | cm | | | | |
| 1899 | 0.02 | 0.02 | 0.02 | 0.02 | | < 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |
| 1900 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1901 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1902 | < 0.01 | 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 |
| 1903 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1904 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1905 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1906 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1907 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1908 | 0.04 | 0.06 | 0.02 | 0.02 | | 0.04 | 0.04 | 0.06 | 0.02 | 0.02 |
| 1909 | 0.13 | 0.13 | 0.13 | 0.13 | | 0.08 | 0.13 | 0.13 | 0.13 | 0.13 |
| v1910 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1911 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1912 | 0.05 | 0.06 | 0.04 | 0.03 | | 0.03 | 0.06 | 0.06 | 0.04 | 0.03 |
| 1913 | 0.10 | 0.10 | 0.10 | 0.10 | | 0.05 | 0.10 | 0.10 | 0.10 | 0.10 |
| 1914 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1915 | 0.02 | 0.02 | 0.02 | 0.01 | | < 0.01 | 0.02 | 0.02 | 0.02 | 0.01 |
| 1916 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1917 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1918 | 0.01 | 0.01 | 0.01 | 0.01 | | < 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 1919 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1920 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1921 | 0.46 | 0.46 | 0.46 | 0.46 | | 0.13 | 0.47 | 0.46 | 0.46 | 0.46 |
| 1922 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1923 | 0.11 | 0.11 | 0.11 | 0.11 | | 0.07 | 0.11 | 0.11 | 0.11 | 0.11 |
| 1924 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1925 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1926 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1927 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1928 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1929 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1930 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1931 | 0.02 | 0.04 | 0.02 | 0.07 | | 0.04 | 0.03 | 0.05 | 0.02 | 0.07 |
| 1932 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1933 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1934 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1935 | 0.03 | 0.03 | 0.03 | 0.03 | | < 0.01 | 0.03 | 0.03 | 0.03 | 0.03 |
| 1936 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1937 | 0.01 | 0.03 | 0.02 | 0 | | 0.03 | 0.01 | 0.03 | 0.02 | < 0.01 |
| 1938 | 0.11 | 0.12 | 0.10 | 0.10 | | 0.04 | 0.11 | 0.12 | 0.10 | 0.10 |
| 1939 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1940 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |

**TABLE D-3**
**SUMMARY OF SIMULATED RUNOFF (100 YEARS) FOR**
**STOCKPILE AND TAILING COVERS TYRONE MINE CCPE (CON'T).**

| Year | Stockpile Covers | | | | | Tailing Covers | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 60 | 60HL[a] | 90 | 120 | | 45 | 60 | 60HL | 90 | 120 |
| | cm | | | | | cm | | | | |
| 1941 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1942 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1943 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1944 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1945 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1946 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1947 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1948 | 0.09 | 0.01 | 0.01 | 0.01 | | < 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 1949 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1950 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1951 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 |
| 1952 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1953 | 0.06 | 0.06 | 0.06 | 0.06 | | 0.02 | 0.06 | 0.06 | 0.06 | 0.06 |
| 1954 | 0.02 | 0.02 | 0.02 | 0.02 | | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |
| 1955 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1956 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1957 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1958 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1959 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1960 | 0.02 | 0.02 | 0.02 | 0.02 | | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |
| 1961 | 0.12 | 0.12 | 0.12 | 0.12 | | 0.08 | 0.12 | 0.12 | 0.12 | 0.12 |
| 1962 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1963 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1964 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1965 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1966 | 0.07 | 0.07 | 0.07 | 0.07 | | 0.04 | 0.07 | 0.07 | 0.07 | 0.07 |
| 1967 | 0.07 | 0.07 | 0.07 | 0.07 | | 0.03 | 0.07 | 0.07 | 0.07 | 0.07 |
| 1968 | 0.10 | 0.10 | 0.10 | 0.10 | | 0.05 | 0.10 | 0.10 | 0.10 | 0.10 |
| 1969 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1970 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1971 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1972 | 0.13 | 0.13 | 0.13 | 0.14 | | 0.08 | 0.13 | 0.13 | 0.13 | 0.14 |
| 1973 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1974 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1975 | 0.09 | 0.09 | 0.09 | 0.09 | | 0.05 | 0.09 | 0.09 | 0.09 | 0.09 |
| 1976 | 0.07 | 0.07 | 0.06 | 0.06 | | 0.02 | 0.07 | 0.07 | 0.06 | 0.06 |
| 1977 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1978 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1979 | 0.03 | 0.04 | 0.02 | 0.02 | | 0.02 | 0.03 | 0.04 | 0.02 | 0.02 |
| 1980 | 0.14 | 0.15 | 0.14 | 0.13 | | 0.06 | 0.14 | 0.15 | 0.14 | 0.13 |

**TABLE D-3**
**SUMMARY OF SIMULATED RUNOFF (100 YEARS) FOR STOCKPILE AND TAILING COVERS TYRONE MINE CCPE (CON'T).**

| Year | Stockpile Covers | | | | | Tailing Covers | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 60 | 60HL[a] | 90 | 120 | | 45 | 60 | 60HL | 90 | 120 |
| | cm | | | | | cm | | | | |
| 1981 | 0.11 | 0.12 | 0.11 | 0.10 | | 0.09 | 0.11 | 0.12 | 0.11 | 0.10 |
| 1982 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1983 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1984 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1985 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1986 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1987 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1988 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1989 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1990 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1991 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1992 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1993 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1994 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1995 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 1996 | 0.07 | 0.07 | 0.07 | 0.06 | | 0.04 | 0.07 | 0.09 | 0.07 | 0.06 |
| 1997 | 0.01 | 0.01 | 0.01 | 0.01 | | < 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 1998 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | | < 0.01 | < 0.01 | 2.41 | < 0.01 | < 0.01 |
| Average | 0.02 | 0.02 | 0.02 | 0.02 | | 0.01 | 0.02 | 0.05 | 0.02 | 0.02 |

[a] high leaf area (peak LAI = 0.42)

**A compact disk with output files from the water balance model**

**accompanies the original submittal of this report.**