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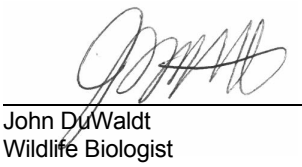
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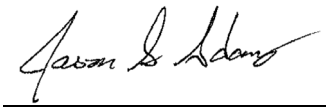
Baseline Technical Report For Soils and Biological Resources, Cresson Project M-1980-0244 Amendment No. 11 Teller County, Colorado

October 2015

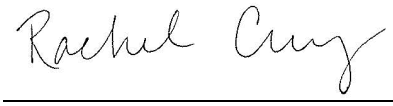
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Baseline Technical Report

Soils and Biological Resources,
Amedment No. 11 Project Area

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EXECTUTIVE SUMMARY

ARCADIS U.S., Inc. (ARCADIS) performed soil and biological resources assessments of the Cripple Creek & Victor Cresson Project as part of the requirements to modify mining operations under the proposed Amendment 11 to the Office of Mine Land Reclamation Board (OMLB) Permit No. M-1980-0244 (Amendment 11). Field investigations of two survey areas were conducted on August 8 and 9, 2015. Soil investigation efforts produced a revised Cresson Project soil map, evaluation of soil resources, and assessment of salvageable secondary growth media within the two survey areas (together referred to as the "Amendment 11 Project area"). Biological investigation efforts produced revised Amendment 11 Project area vegetation and wildlife resources maps and evaluation of the vegetation and wildlife resources within the Cresson Project, including special status species. Potential impacts to soil and biological resources were also evaluated and recommendations for resource use and impact mitigation are provided.

1. INTRODUCTION

Cripple Creek & Victor Mining Company (CC&V) of Newmont Mining Corporation is proposing to extend mining operations at the CC&V Cresson Project in the Cripple Creek Mining District (District) in Teller County, Colorado (**Figure 1**). The proposed project, referred to as Amendment No. 11 Project, would occur on approximately 186 acres north and west of existing operations. Lands within the Amendment 11 Project area are owned or controlled by CC&V. The proposed project requires that CC&V submit a modification to the existing state mining permit to the Colorado Division of Reclamation, Mining, and Safety (DRMS).

As part of the permit modification, CC&V must fulfill requirements specified in the "Hard Rock/Metal Mining Rules and Regulations of the Colorado Mined Land Reclamation Board (CMLRB)" as well as requirements per Teller County land use regulations. To meet these requirements, ARCADIS, on behalf of CC&V, collected baseline resource information on soils and biological resources (vegetation, wildlife, and special status species). This report summarizes the baseline information collected for these resources.

1.1 Project Area Description

The Cresson Project is located between the towns of Cripple Creek and Victor in Teller County, Colorado. It is a low-grade, surface gold mining operation where the ore is treated using a valley-type, heap-leach process with activated carbon used to recover

the gold. The proposed Amendment 11 Project area is located within lands owned or controlled by CC&V surrounding the Cresson Mine. The legal descriptions of the Amendment 11 Project survey areas are:

- Survey Area 1: Township 15 South, Range 69 West, Section 18 and Township 15 South, Range 70 West, Section 13
- Survey Area 2: Township 15 South, Range 69 West, Section 16

Collectively these two survey areas are referred to as the "Amendment 11 Project area" for the purposes of this report. The Amendment 11 Project area ranges in elevation from approximately 9,560 feet (2,914 meters) to 10,250 feet (3,139 meters) above mean sea level (amsl). Vegetation communities are relatively diverse consisting of communities such as grasslands, woodlands, and wet meadows. Geology in the District consists of an Oligocene-aged (approximately 30 million years ago) diatreme-volcanic, intrusive complex surrounded by Precambrian rocks. The eastern portion of the District is characterized by a flat-lying sequence of volcanoclastic sediments and phonolite flow units. The central portion of the District is dominated by complex flow dome structures with cross-cutting intrusive dikes and sills. The western side of the District contains extensive areas of diatremal volcanoclastic breccias with scattered intrusive and flow dome features (Vardiman et al. 2006).

1.2 Survey Methods

1.2.1 Phase I – Compile Existing Data

ARCADIS performed a detailed compilation of existing resource information available for the Amendment 11 Project area. The Amendment 11 Project area is part of the larger Cresson Project area that encompasses most of the District and consists of two smaller survey areas (**Figure 1**). Based on the information required by the CMLRB and Teller County for the permit amendment, information on the following resources was compiled:

- Soil resources, including plant growth medium;
- Vegetation resources;
- Wildlife resources; and
- Special status species (Threatened, Endangered, Sensitive and Candidate Species [TECS] and Colorado sensitive wildlife and plant species).

1.2.1.1 Soil Resources

Previous soil surveys were conducted within the Cresson Project area by Nerco Minerals Company in 1984 and by Newport Minerals in 1985. These surveys were conducted in the northern portion of the District. Preliminary soil mapping was conducted by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) (Soil Conservation Service prior to 1994) in 1993 and 1995. At that time, three dominant soil units were identified within the Cresson Project area:

- Grenadier-like-Unnamed very gravelly loam complex (HL);
- Quander-Varden complex (PF); and
- Rogert very gravelly sandy loam.

In 1996, CC&V conducted a modified Order II soil survey to map a portion of the Cresson Project area to the series level in support of the Amendment No. 7 project (JBR 1997). Approximately 60 soil pits were used to determine soil characteristics in the field including the soil depth, types of horizons, parent material, structure, texture, color, pores, stoniness, roots, and other special characteristics. The mapped soils were identified to the soil series level where possible, using named soil associations identified by the NRCS.

ARCADIS/Greystone conducted modified Order II soil surveys in support of the Amendment No. 9, and Mine Life Extension (Amendment No. 10) projects (ARCADIS 2007, 2011). Prior to the 2011 survey, NRCS updated soils mapping for parts of Teller and Park counties, including the survey area. At that time, information on NRCS soil units in the survey area was available via the Web Soil Survey website (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm), which was developed by the NRCS to provide access to the most current soil data. A review of the updated soil spatial (Version 4, May 19, 2008) and tabular data (Version 4, March 7, 2008), indicated discrepancies between previous JBR Environmental Consultants (JBR) soil mapping, Greystone and ARCADIS soil mapping, and NRCS mapping current as of 2011.

Similarly, prior to the 2015 surveys, NRCS again updated soil data within the District (Spatial Data Version 6, December 23, 2013; Tabular Data Version 7, September 22, 2014). Prior to conducting field surveys, ARCADIS downloaded the 2013 data from Web Soil Survey and reviewed the data to identify discrepancies between the 2011 ARCADIS soil survey and the 2013 NRCS data. Within the revised tabular data,

NRCS now also provides interpretation of various soil suitabilities and limitations, including for use as a source of reclamation material. These interpretations are incorporated into the discussion of growth media in Section 2.2. NRCS has also modified soil map unit indicators from alphabetic (e.g., CQ, SZ, etc.) to numeric (e.g., 3, 16, etc).

1.2.1.2 Vegetation Resources

Existing baseline information on vegetation resources in the Amendment 11 Project area was collected, compiled, and reviewed for completeness and accuracy. The existing baseline information was primarily based on past field surveys and vegetation mapping efforts completed by JBR in 1997 in support of Amendment No. 7, by Greystone in 1999 in support of Amendment No. 8, by ARCADIS in 2007 in support of Amendment No. 9, and by ARCADIS in 2011 in support of Amendment No. 10.

1.2.1.3 Wildlife Resources

ARCADIS compiled baseline information on wildlife resources by reviewing data from CC&V's files (CC&V 1992, 1993, and 1998); wildlife inventories performed by Colorado Division of Wildlife (CDOW) in 1997 as well as 2015 game species occurrence data from Colorado Parks and Wildlife (CPW) databases and websites; and wildlife inventories performed by ARCADIS in 2011. In addition, existing information from past U.S. Fish and Wildlife Service (USFWS) consultation, publicly available published/unpublished literature, maps, population data, and any other applicable information were qualitatively evaluated, integrated, and used to develop the baseline description of the project area's existing wildlife.

1.2.1.4 Special Status Species

Several literature reviews and field surveys for special status species have been conducted for the Cresson Project in the past. However, because species lists are frequently updated, ARCADIS reviewed recent publicly available literature to determine which currently listed special status species have potential to occur in the Amendment 11 Project area.

ARCADIS first conducted a literature search for federally listed TECS. TECS are identified by the USFWS under the provisions of the Endangered Species Act of 1973, as amended. The website for the USFWS was queried for a list of TECS that have potential to occur in the District/Teller County (USFWS 2015). CPW maintains a state list of threatened and endangered wildlife species and also lists some wildlife species with declining populations as 'species of special concern.' The CPW website was

queried to determine state-listed threatened, endangered, and species of concern that have potential to occur in the Amendment 11 Project area (CPW 2015). In addition, the Colorado Natural Heritage Program (CNHP) maintains a list of rare plant species for the state, which includes rare plant species as listed by the U.S. Forest Service (USFS) and Bureau of Land Management (BLM) (CNHP 2014). From these initial lists, ARCADIS narrowed the list of potential special status species that could occur in the Amendment 11 Project area based on each species' habitat requirements. Species with no suitable habitat in the Amendment 11 Project area were eliminated from further consideration.

1.2.2 Phase II – Collect Baseline Data

Once existing baseline information was compiled, ARCADIS conducted field surveys and inventories on August 8 and 9, 2015 to verify and update the existing information in the Amendment 11 Project Area, as appropriate. Field surveys and inventories included:

- Soil profile investigations and soil mapping,
- Vegetation mapping (map and characterize vegetation community types in the Amendment 11 Project area),
- Raptor nest survey,
- Habitat assessment for special status species (confirm presence or absence of suitable habitat),
- Inventory of wildlife species, and
- Inventory of plant species.

Once field work was completed, ARCADIS summarized relevant information for each resource (soils, vegetation, wildlife, and special status species) and identified any additional information or modifications to the existing baseline description for the Amendment 11 Project area. This information is summarized in the results below.

2. SOIL AND GROWTH MEDIUM RESOURCES

In order to be consistent with published data, this report presents a revised soils map based primarily on current NRCS data available through the Web Soil Survey. NRCS data have been supplemented by data collected during the reconnaissance soil survey conducted by Greystone from August 16 to 20 and September 22 to 24, 1999; a survey by ARCADIS on June 21 and 22, 2007; a survey by ARCADIS from July 19 to 21, 2011; and the July 8 and 9, 2015 survey described herein. Field investigations by ARCADIS in 2015 focused on two survey areas within the Amendment 11 Project area. Data collected within the survey areas are considered to represent a more detailed level of analysis than NRCS data, and map unit boundaries have been adjusted accordingly. In addition, aerial photography of the District taken in September 2014 was utilized to more accurately define soil map unit boundaries. Since the 2011 ARCADIS survey and report, NRCS has revised the soil map units mapped within the Cresson Project. These revisions are described on a map unit basis below.

A revised soil map of Amendment 11 Project area soils is presented as **Figure 2**. Characteristics of the soil types in the area are summarized below and in **Table 2-1**. **Table 2-2** identifies characteristics of the soil map units within the Amendment 11 Project area. Soil map unit 76 (Disturbed land, mine areas, overburden storage areas, mine complex) is not included in **Table 2-2** due to the lack of suitable soils for reclamation. Unit 76 varies for all characteristics depending on the age, amount, and type of disturbance and original character of the soil.

Soil surveys of the project area were conducted concurrently with vegetation mapping, which allowed for close correlation of mapped soil units with vegetative cover. In addition, soil units were differentiated based on geology, aspect, and slope steepness. Exposed soil profiles in road cuts, walls of exploration pits, and other excavations were examined where feasible and safe. Soil pits were excavated where exposed soils did not exist. In order to confirm accurate mapping by NRCS, soil exposures and pits were selected for examination based on slope, aspect, parent material, and vegetation present that matched published descriptions of the soil unit mapped by NRCS at that specific location.

2.1 Soil Resources

This section summarizes the soil resources observed within the 2015 project area as well as the larger Cresson Project area as determined through review of NRCS soil mapping and previous baseline studies. The names of soil units within the Cresson Project area have changed repeatedly over recent years. This report uses current

NRCS terminology and explains the general correlation between current and previous soil unit names. Soil map units 3, 14, 19, 21, and 59 were not observed within the project area but are described for reference as they are present within the greater Cresson Project area.

2.1.1 3. Adderton-Platdon association, 0 to 6 percent slopes

These soils are hydric or partially-hydric alluvial soils found on grassy stream terraces, toe slopes and floodplains in the Cresson Project area. Adderton series soils are deep, loamy, and well drained, whereas the Platdon series soils are shallower, poorly drained, and have coarser texture. This unit was been variably mapped as map unit CQ (Adderton-Rosane taxadjunct complex, 0 to 6 percent slopes) and Hydric Soils in previous surveys. Platdon series soils replace the Rosane and Cryaquoll soils previously included in the CQ map unit. This map unit was not observed during the 2015 survey.

2.1.2 14. Bushpark-Seitz association, 15 to 50 percent slopes

These soils are found on a single south-facing mountainside in the eastern portion of the Cresson Project area and are associated with the conifer-dominated woodland vegetation community type. Soils in this association are formed from colluvium or slope alluvium formed from volcanic breccias and are very to extremely gravelly loam and well drained. Seitz series soils are deeper than Bushpark series soils and have a thin upper horizon composed of decomposed organic material. The small area mapped as this unit by NRCS was previously mapped solely as Seitz series soils (ARCADIS 2007). This map unit was not observed during the 2015 survey.

2.1.3 17. Catamount-Guffey complex, 15 to 40 percent slopes

These soils are found on mountainsides in the northeastern portion of the Cresson Project area and are associated with conifer-dominated and mixed conifer-aspen woodlands. Soils in this complex are formed in colluvium or slope alluvium derived from granite, gneiss, or schist. Catamount soils are shallow gravelly sandy loams whereas Guffey soils are moderately deep gravelly sandy loams with an accumulation of clay at depth (Bt horizon). The distribution of this unit is similar to previous NRCS mapping within the area; however, survey observations indicate that the unit extends further to the north than mapped by NRCS. This is the dominant soil map unit within Survey Area 2. Approximately 35.4 acres of this soil map unit (mostly Catamount series) are present within the Amendment 11 Project area, all within Survey Area 2.

2.1.4 19. Cathedral very gravelly sandy loam, 15 to 40 percent slopes

These soils are found on south-facing mountainsides in the southern portion of the Cresson Project area. These are shallow to very shallow stony or gravelly sandy loam that have formed in slope alluvium and colluvium from granite, monzonite, schist, or gneiss. This map unit replaces areas previously mapped by NRCS as Rogert very gravelly sandy loam, 15 to 40 percent slopes. This map unit was not observed during the 2015 survey.

2.1.5 21. Cathedral-Rock outcrop complex, 20 to 60 percent slopes

This soil unit consists of areas where cliffs and rock outcrops occur comingled with Cathedral series soils on steep mountainsides. Cliffs and rock outcrops may compose 30 percent of the unit. This map unit replaces areas previously mapped by NRCS as Rogert-Rock Outcrop complex, 20 to 60 percent slopes. Some areas previously mapped as this unit have been disturbed by mining operations. This map unit was not observed during the 2015 survey.

2.1.6 59. Ivywild-Catamount complex, 30 to 70 percent slopes

Within the Cresson Project area, these soils are found on north-facing mountainsides in association with the dense conifer-dominated woodland vegetation type, and some areas of transitional aspens. Both components have formed from colluvium and residuum derived from granite. Both soils are somewhat excessively drained, shallow, and consist of gravelly sandy loam or loamy coarse sand. Catamount soils are shallower and contain more gravel at depth. Distribution of this map unit is generally consistent with previous NRCS mapping but has been re-mapped as units 19 and 88 in some areas. This map unit was not observed during the 2015 survey.

2.1.7 76. Disturbed land, mine areas, overburden storage areas, mine complex

Areas that were historically mined or otherwise altered by human activities are classified as disturbed soils. Surface disturbance was identified from September 2014 aerial photography and field observations. Differences in vegetation were also used in mapping these units, as some vegetation (particularly aspen-dominated woodland) has developed on disturbed areas through succession from surrounding vegetated areas. Portions of this map unit may have incipient soils formed on mine tailings or native soil remaining, but the unit is dominated by disturbed soil to the point where salvage of secondary growth medium is unfeasible from this unit. This map unit replaces unit DS used in the 2007 Baseline Report (ARCADIS 2007) and unit OR in the 2011 Baseline Report (ARCADIS 2011) in order to be consistent with NRCS mapping. Areas of

disturbed land occur as minor components of all map units observed in the project area. This map unit is associated with recent and historical mining activity in the Amendment 11 Project area, including right-of-way construction in Survey Area 2. Approximately 42.6 acres of this unit are present in the Amendment 11 Project area (39.4 acres in Survey Area 1; 3.2 acres in Survey Area 2).

2.1.8 82. Quander-Bushpark very gravelly loams, 5 to 40 percent slopes

These soils are found on mountainsides and face terraces. Both components are derived from colluvium and residuum composed of breccias and tuff, are very to extremely gravelly loams and clay loams, and are well drained. Both series are characterized by subsoil composed of angular cobble-sized rock fragments. Bushpark series soils are shallower, found on steeper slopes, and are most commonly associated with aspen-dominated plant community types. Bushpark soils observed in the Amendment 11 Project area are slightly deeper than the NRCS typical soil profile. Quander soils are most commonly associated with natural or disturbed grasslands.

This is the dominant soil map unit within Survey Area 1. The unit comprises approximately 89.7 acres of Survey Area 1, with Quander soils representing 40 percent (35.7 acres) and Bushpark 60 percent (54.0 acres). Areas of soil unit 82 in the southern part of Survey Area 1 are currently mapped by NRCS as unit 97 (Seitz very gravelly loam, 20 to 50 percent slopes), but are reclassified as Bushpark series soils due to the lack of an O horizon and lack of an albic B horizon, among other characteristics. This map unit was not observed in Survey Area 2.

Previous soil surveys of the Cresson Project variably mapped Quander series soils as the Ess series soils of the former EB soil map unit or as part of the Quander-Varden complex soil unit (PF). The EB and PF soil map units are both herein discontinued for consistency with NRCS mapping. In addition, some areas in the northern portion of the Cresson Project area previously mapped by as Rogert series soils in 2004 and 2007 are now mapped as soil unit 82. Similarly, in revised NRCS data the Quander-Bushpark map unit includes areas previously mapped as Rogert, Ivywild, and Catamount series soils by NRCS in 2011.

2.1.9 88. Rofork very gravelly sandy loam, 5 to 55 percent slopes

This map unit is generally found on south-facing mountain slopes in association with the natural grassland vegetation community type within the Cresson Project area. Rofork series soils are very gravelly sandy loam or loamy coarse sand that have formed in slope alluvium and residuum derived from granitic rocks, schist, and gneiss.

Approximately 2.5 acres of this soil map unit are present within the Amendment 11 Project area, all within Survey Area 2. This map unit largely replaces areas mapped by NRCS in 2011 as Herbman gravelly sandy loam, 5 to 55 percent slopes.

2.1.10 97. Seitz very gravelly loam, 20 to 50 percent slopes

Seitz series soils are found on mountainsides with the dense conifer-dominated woodland vegetation type and in some areas of transitional aspen forests. These soils consist of very gravelly loams and clay loams to a depth of approximately 24 inches, which overlie a subsoil composed of very angular cobbles. A thin surface layer composed of decomposing conifer needles and other vegetation is often present within the Amendment 11 Project area. Approximately 15.1 acres of this soil map unit are present within the Amendment 11 Project area, all within Survey Area 1. The distribution of this soil unit is generally consistent with previous NRCS mapping but has been partially re-mapped as unit 82 in portions of the Cresson Project area, including part of Survey Area 1.

2.2 Growth Medium Resources

Soils that are suitable for assisting with revegetation are salvaged as part of the ongoing mining operations at the Cresson Project. Soil recovered for use during reclamation is termed growth medium. The volume of growth medium that can be salvaged from areas proposed for disturbance is primarily limited by the amount of coarse rock fragments. Large coarse fragments (stones and larger) limit operators' ability to strip and stockpile soil, and all coarse fragments contribute to the inability of the soil to hold water for vegetation). In addition, depths of less than 6 inches are typically considered to be unsalvageable due to the large size of the equipment used to recover soil for reclamation purposes. The depth of potentially salvageable soil varies greatly depending on terrain position, with the shallowest soils typically occurring on upper slopes and deepest soils at the toe of slopes. Although not observed extensively within the project area, the presence of small rock outcrops may also render salvage operations unmanageable.

Given the factors described above and data from field surveys, an average growth medium salvage depth was determined for each component of mapped soil units (**Table 2-3**). Suitability ratings are based on guidance provided by NRCS and USDA as summarized in **Table 2-4**. NRCS interpretations of suitability and limiting factors are also provided for comparison; however, these interpretations do not reflect site-specific observations or the suitability guidance previously provided for the Cresson Project (NRCS 1999). NRCS interpretations are made for soil map units and soil profiles as a

whole and do not account for the fact that more suitable soils are often found near the top of soil profiles.

Four suitability ratings (Good, Fair, Poor, and Unsuitable) were used to determine the salvage depths of each mapping unit. Coarse fragment content is primarily responsible for the suitability ratings in **Table 2-3**. Growth medium suitability generally decreases with depth as coarse fragment content increases. Soils with more than 50 percent cobble or larger fragments are rated unsuitable for use as growth medium. Low organic content may also somewhat limit the suitability of some soils (e.g., Quander and Bushpark series). Field tests of soil pH did not indicate any additional limitations to use of project area soils as secondary growth medium. Good quality soil growth medium may be salvaged from the Catamount and Platadon series soils. The Platdon, Quander, Bushpark, and Seitz series soils contain salvageable amounts of fair quality soil growth medium. During salvage and clearing/grubbing operations, removing large roots and stumps and pushing slash often mixes soil horizons; therefore, the ratings provided in **Table 2-3** are intended to inform salvage and reclamation and do not represent strict salvage guidelines. Soils rated as poor are considered acceptable for reclamation purposes but may require treatment (e.g., screening out large rock fragments or adding additional organic material) to facilitate successful reclamation.

Estimated volumes of salvageable soil growth medium were calculated using suitability ratings, average growth medium depths, and soil distributions presented in **Tables 2-2, 2-3,** and **2-4**. Soil components with average growth medium depths of less than 6 inches were not included in the total amount of salvageable material due to complications associated with salvaging shallow soils with heavy equipment. Previously disturbed soils (map unit 76) were also not included in calculations. Previously disturbed soils were observed to support vegetation in the Squaw Gulch and Chicago Portal areas but do not contain sufficient soil to represent a source of secondary growth medium.

Based on mapped distributions of soil components and interpretations of depth and suitability, approximately 627,000 cubic yards of suitable growth media is present within the Amendment 11 Project area. Soils rated as good comprise approximately 6 percent of the total (37,000 cubic yards), fair soils comprise 25 percent (157,000 cubic yards), and poor soils comprise approximately 69 percent (434,000 cubic yards). These estimates suggest that all areas within the Amendment 11 Project area could be potentially reclaimed with approximately 24 inches of secondary growth medium.

Within Survey Area 1, approximately 457,000 cubic yards of suitable growth media are available for salvage. Of this, approximately 39 percent (178,000 cubic yards) are soils rated as fair and 61 percent (279,000 cubic yards) are rated as poor.

Within Survey Area 2, approximately 62,000 cubic yards of suitable growth media are available for salvage. Of this, approximately 59 percent (37,000 cubic yards) are soils rated as good, less than 1 percent (500 cubic yards) are soils rated as fair, and 40 percent (25,000 acres) are soils rated as poor.

3. VEGETATION RESOURCES

A qualified ARCADIS biologist mapped and characterized vegetation types within the Amendment 11 Project area from August 8 to 9, 2015. The survey areas constituting the Amendment 11 Project area have been, and continue to be, disturbed by historic and ongoing mine-related activities (e.g., underground development, rock piles, prospecting excavations, surface mines, overburden storage areas, structures, and roads). A mosaic of several distinct vegetation communities persists within the survey areas. Field verification and modification of baseline vegetation information resulted in the identification of eight vegetation community types within the Amendment 11 Project area. **Table 3-1** summarizes the distribution of vegetation communities within survey areas. Each of these vegetation communities is described below. **Appendix A** includes the common name and scientific nomenclature for each plant species identified within the Amendment 11 Project area. Taxonomic names conform to Weber and Wittman (1996). Plant communities within the Amendment 11 Project area are also mapped on **Figure 3**.

3.1 Aspen-Dominated Woodland

Aspen-dominated woodland accounts for approximately 63.1 acres (34 percent) of the Amendment 11 Project area (**Table 3-1**). This plant community can be found in Survey Area 1. Within Survey Area 1, interior portions of aspen-dominated woodland stands have a closed 15- to 65-foot (5- to 20-meter) tall canopy dominated by quaking aspen (*Populus tremuloides*). Margins of woodland stands and adjacent areas recently colonized by aspen have shorter and sparser trees. Several conifer species are subdominant components of these woodland stands including subalpine fir (*Abies lasiocarpa*), Englemann spruce (*Picea engelmannii),* limber pine (*Pinus flexilis*), lodgepole pine (*Pinus contorta*), Colorado blue spruce (*Picea pungens*), ponderosa pine (*Pinus ponderosa*), and Douglas fir (*Pseudotsuga menziesii*). Of these species, Engelmann spruce and limber pine appear to be the most common coniferous species occurring in aspen-dominated woodlands within the Amendment 11 Project area. The presence of the conifer species suggests that the long-term trajectory of aspen-dominated woodlands is toward mixed conifer stands. Conifer species may contribute up to 15 percent of the tree canopy before the community would be reclassified as a mixed conifer/aspen plant community. Shrubs are not common within this vegetation community. The herbaceous layer is generally lush, constituting the majority of understory cover (approximately 50% and greater cover). Common grasses include blue wild-rye (*Elymus glaucus*), slender wheatgrass (*Elymus trachycaulus*), fringed brome (*Bromus ciliatus*), and Arizona fescue (*Festuca arizonica*). The most common forb in the understory of aspen-dominated woodlands

in the Amendment 11 Project area is golden banner (*Thermopsis montana*). Other forbs include yarrow (*Achillea millefolium*), meadow-rue (*Thalictrum fendleri*), cinquefoil (*Potentilla ovina*), fireweed (*Chamerion danielsii*), clover (*Trifolium* sp.), and milk vetch (*Astragalus* sp.).

3.2 Dense, Conifer-Dominated Woodland

Dense, conifer-dominated woodland accounts for 36.5 acres (20 percent) of the Amendment 11 Project area and occurs primarily in Survey Area 2. This is a mixed stand of lodgepole pine and aspen with subcomponents of Englemann spruce and limber pine situated on a rocky northeast-facing slope. The toe slope area contains a stand of Englemann and Colorado blue spruce. This is primarily a younger, secondary succession forest heavily stocked with small to medium size class trees and fewer mature height (69-foot [18.3-meter]) trees. The understory is dominated by common juniper, forbs, and shrubs including golden banner, daisy (*Erigeron* sp.), bearberry, and dwarf bilberry. Shrubby cinquefoil (*Dasiphora [Pentaphyloides] floribunda*) is also present on the lower slope of Survey Area 2. Other forbs include milkvetch, yarrow, pussytoes (*Antenniaria rosea*), columbine (*Aquilegea* sp.), geranium (*Geranium caespitosum*), and harebell (*Campanula rotundifolia*).

3.3 Mixed Conifer/Aspen-Dominated Forest

Survey Area 1 contains a 15.1-acre stand of mixed conifer/aspen-dominated forest (8 percent of the Amendment 11 Project area). Although the stand is dominated by large mature aspen trees, Englemann spruce and, to a lesser extent, limber pine is replacing the aspen and will probably overtake the aspen in coming decades. Understory/groundcover is relatively sparse and includes golden banner, violet (*Viola* sp.), wild strawberry, mountain muhly (*Muhlenbergia montana*) and fringed brome.

3.4 Natural Grassland

Natural grasslands account for approximately 10.7 acres (6 percent) of the Amendment 11 Project area and occur in Survey Areas 1 and 2. Natural grasslands in the Amendment 11 Project area have a species composition and density that has not substantially changed as a result of disturbance. Cover is relatively high and ranges from 60 to 90 percent. Natural grasslands occur on gentle to moderate slopes with variable exposures. Dominant species include Parry's oatgrass (*Danthonia parryi*), junegrass (*Koelaria macrantha*), Kentucky bluegrass (*Poa pratensis*), mountain muhly, squirreltail (*Elymus elymoides*), western wheatgrass (*Pascopyron smithii*), bearded wheatgrass, and Arizona fescue. Grassy slope sedge (*Carex oreocharis*) (once

considered a rare species by the Colorado Natural Heritage Program, but not currently) occurs in this plant community on granitic soils. Noxious weeds are generally not present or are sporadic in nature within natural grasslands.

3.5 Disturbed Grassland

Disturbed grasslands account for approximately 10.0 acres (5 percent) of the Amendment 11 Project area and occur in Survey Area 1, adjacent to the active mine site. These grasslands have been disturbed in historical times (primarily as a result of older mining activities and road or utility construction) and continue to be disturbed by ranching practices (cattle grazing) and road construction/adjacent mining operations. This vegetation community is primarily distinguished from the "Disturbed Area" vegetation community type (see Section 3.9) by having a higher overall plant cover, dominated by grass species. Disturbed grasslands occur on gentle slopes with a southern exposure in the Amendment 11 Project area. The composition, density, and cover of vegetation (30-60 percent) have been substantially altered. Dominant species include Kentucky bluegrass, western wheatgrass, squirreltail, redtop (*Agrostis stolonifera*), junegrass, green needlegrass, Arizona fescue, and smooth brome (*Bromus inermis*). Several noxious weed species are present, including but not limited to Canada thistle (*Cirsium arvense*), bull thistle (*Cirsium vulgare*), and dalmatian toadflax (*Linaria dalmatica*).

3.6 Riparian Woodland

Riparian woodlands were not observed during the survey of the Amendment 11 Project area. A drainage channel trending northeast to southwest through Survey Area 1 has a mosaic of vegetation cover types including aspen forest, bare ground as a remnant of historical mining activity, and savanna-like conifer meadow. None of these classify as true riparian woodland, likely due to the intermittent nature of streamflow.

3.7 Wet Meadow

Wet meadows account for 0.3 acres (0.1 percent) of the Amendment 11 Project area, only occurring in the lower, northern portion of Survey Area 2. Moisture for this community appears to come from groundwater, stream discharge, overland flow, and on-site precipitation. A delineation of potential wetlands was not conducted, however wet meadow acreage in Survey Area 2 may be a jurisdictional wetland under Section 404 of the Clean Water Act (CWA). The Survey Area 2 wet meadow contains a variety of hydrophytic plant species, including sedges (*Carex* spp.), tufted hairgrass

(*Deschampsia caespitosa*), shrubby cinquefoil, a spikerush species (*Eleocharis spp.*), Baltic rush (*Juncus balticus.*), marsh marigold (Caltha leptosepala), wild iris (*Iris missouriensis*), buttercups (*Ranunculus* spp.), American bistort (*Bistorta bistoroides*), and Sphagnum moss (*Sphagnum* spp.). The area had been disturbed by grazing (likely Rocky Mountain elk, *Cervus canadensis*) and the water table was at the ground surface in a portion of the wet meadow with surface runoff originating from one or more springs.

3.8 Disturbed Areas

Disturbed areas are a result of past and ongoing mining and ranching practices. Disturbed areas account for approximately 50.0 acres (27 percent) of the Amendment 11 Project area (46.8 acres in Survey Area 1; 3.2 acres in Survey Area 2). Most or all of the soil has been disturbed, and vegetation is dramatically changed, diffuse, or absent in these areas. Where vegetation occurs, it is typically a mix of native and non-native grasses, forbs, and noxious weeds. This is an ecologically-distinct vegetation community type and is mapped separately from "Disturbed Grasslands" (see Section 3.6 and **Table 3-1**).

3.9 Noxious Weeds

Noxious weeds are primarily associated with disturbed areas and roadsides. The most commonly noted species were yellow toadflax (*Linaria vulgaris*), with lesser amounts of Canada thistle, musk thistle (*Carduus nutans*), oxeye daisy (*Chrysanthemum leucanthemum*), bull thistle, cheatgrass (*Bromus tectorum*), and Dalmatian toadflax. These species do not presently appear to be displacing native vegetation.

3.10 Potential Impacts to Vegetation Resources

Reclamation performance standards per Rule 3 of the Mineral Rules and Regulations of the CMLRB for Hard Rock, Metal, and Designated Mining Operations (CMLRB 2010) will be implemented for post-mining use. CC&V's site-wide reclamation plan sets restoration goals based on past and expected post-mining land uses.

A delineation of potential wetlands and other waters of the U.S. for the areas of new disturbance included in the Amendment 11 Project area was not performed during August 2015 fieldwork. Wetlands and other waters of the U.S. are regulated under Section 404 of the CWA and authorization (a Section 404 permit) is required for the placement of dredged and fill material into them. One potential wetland was located in

Survey Area 2 and is likely a 1.3-acre jurisdictional wet meadow wetland which extends beyond the Amendment 11 Project area boundary.

4. WILDLIFE RESOURCES

ARCADIS conducted an inventory of wildlife habitats and species within the Amendment 11 Project area in conjunction with evaluating vegetation communities from August 8 to 9, 2015. Important observations are discussed in detail below.

4.1 Big Game

Prior to surveys, existing baseline information indicated that the Rocky Mountain elk is the most abundant big game species within the Amendment 11 Project area. CPW habitat mapping (2015) indicates that the area provides summer and overall ranges, while winter range is found 3,000 feet northeast of Survey Area 2. Elk sign (primarily pellet groups and tree rubs) were observed in several locations throughout the project area, particularly in aspen-dominated woodlands, open conifer-dominated woodlands, and dense conifer-dominated woodlands. A group of approximately 20 elk was observed walking west near the southern boundary of Survey Area 2 on August 8.

CPW habitat mapping (2015) indicates that the Amendment 11 Project area provides summer and overall ranges for mule deer (*Odocoileus hemionus*), with winter range located west and south of the Amendment 11 Project area. Mule deer sign in the form of pellets was observed in several locations throughout all vegetation communities in the Amendment 11 Project area during the wildlife inventory. One mule deer doe was encountered on the edge of an aspen stand in Survey Area 1.

Moose (*Alces alces*) are relatively new inhabitants of Teller County. Moose were reintroduced to north-central Colorado starting in 1978. It is thought that a breeding population did not exist in Colorado in recent times prior to reintroduction (Armstrong, Fitzgerald, and Meaney 2011). The species is now established along the Continental Divide and areas on the west side of the Front Range, including parts of Teller County. At least one individual bull was observed in the vicinity of the Amendment 11 Project area in the summer of 2015 (Chris Hanks, personal communication). Moose require dense vegetation for browsing and thus show preference for early successional stands. Major food plants include willow, spruce, fir, aspen, alder and birch. Home ranges in North Park, Colorado varied up to 135 square miles (Armstrong, Fitzgerald, and Meaney 2011). Evidence suggests that the Amendment 11 Project area currently falls within the home range of one or more moose.

Bighorn sheep (*Ovis canadensis*) do not generally occur within the District, but areas of bighorn sheep overall and winter ranges are found several miles to the northeast and

southwest (CPW 2011). No bighorn sheep, sign of bighorn sheep, or habitat suitable for this species was observed in the Amendment 11 Project area.

The Amendment 11 Project area is part of black bear (*Ursus americanus*) overall range, and is also designated a human/bear conflict area (CPW 1997). Conflict areas are those portions of the overall range where two or more confirmed black bear complaints per season were received which resulted in CPW investigation, damage to persons or property, and/or removal of the problem bear(s). Black bear sign in the form of scat and claw marks on aspen were observed in an aspen-dominated woodland in Survey Area 1, and claw marks and a minimal amount of shredded downed logs where observed intermittently in other aspen stands.

4.2 Game Birds

Existing baseline information indicated that the dusky grouse (*Dendragapus obscurus*) is the only game bird species expected to occur within the Amendment 11 Project area. The mix of dense conifer stands and aspen groves in Survey Areas 1 and 2 provide ideal dusky grouse habitat. However, no dusky grouse or sign were observed in the Amendment 11 Project area.

4.3 Raptor Nests

Raptors observed in the Amendment 11 Project area included red-tailed hawk (*Buteo jamaicensis*), Swainson's hawk (*Buteo swainsoni*), American kestrel (*Falco sparverius*), great horned owl (*Bubo virginianus*), and turkey vulture (*Cathartes aura*). These raptors were generally observed soaring or perched; no active nests were observed. An adult red-tailed hawk was observed hunting in Survey Area 1, suggesting that this and adjacent terrain is a potential nesting territory; however, no nest was confirmed. On August 9 a juvenile great horned owl was observed roosting on top of a telephone pole in the Chicago Portal area. This individual flushed uphill into adjacent aspen woodlands and was observed twice more in mature aspen stands south of and adjacent to the Chicago Portal. No tree nest was located; however, historic mine structures in the area may harbor a nest

4.4 Other Wildlife Species

Several small game and nongame species occur in the Cresson Project area and are typical of the high-elevation habitat present, including bird species such as the gray jay (*Perisoreus canadensis*), common raven (*Corvus corax*), black-billed magpie (*Pica pica*), northern flicker (*Colaptes aurates*), downy woodpecker (*Picoides pubescens*),

dark-eyed junco (*Junco hyemalis*), mountain chickadee (*Poecile gambeli*), Clark's nutcracker (*Nucifraga columbiana*), yellow-rumped warbler (*Dendroica coronata*), mountain bluebird (*Sialia currucoides*), chipping sparrow (*Spizella passerina*), American robin (*Turdus migratorius*), white-breasted nuthatch (*Sitta carolinensis*), red-breasted nuthatch (*Sitta canadensis*), mourning dove (*Zenaida macroura*), Steller's jay (*Cyanocitta stelleri*), and barn swallow (*Hirundo rustica*); reptile species such as the garter snake (*Thamnophis* spp.); carnivorous mammals such as the coyote (*Canis latrans*), red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), and mountain lion (*Felis concolor*); and rodents such as the golden-mantled ground squirrel (*Callospermophilus lateralis*), Botta's pocket gopher (*Thomomys bottae*), meadow vole (*Microtus pennsylvanicus*), mountain cottontail rabbit (*Sylvilagus nuttallii*), pine squirrel (*Tamiasciurus hudsonicus*), Gunnison's prairie dog (*Cynomys gunnisoni*), and deer mouse (*Peromyscus maniculatus*).

Shafts and adits associated with historic underground mining in the Cresson Project area represent potential habitat for bat species such as the sensitive Townsend's big-eared bat (*Corynorhinus townsendii*). Suitable foraging habitat for bats exists along unnamed tributaries to Cripple Creek in the Amendment 11 Project area. No underground surveys for bats were conducted during the 2015 site visit and no bats were observed.

4.5 Potential Impacts to Wildlife Resources

Proposed Amendment 11 Project activities in Survey Area 1 may result in the loss of limited amounts of foraging and calving habitat for big game (particularly elk and mule deer), strutting habitat for grouse, habitat for small mammals, and potential nesting habitat for raptors and other migratory birds. These impacts are limited by the recreational Buffer Contact between CC&V and Teller County which limits the amount of surface disturbances within Survey Area 1 to those disturbances necessary to support underground operations. If surface disturbances occur within Survey Area 2, similar types of impacts would occur; however, disturbances in that area are not planned at this time. Per CMLRB's mining rules and regulations (CMLRB 2010), all aspects of the mining and reclamation plan should take into account the safety and protection of wildlife on the mine site, at processing sites, and along all access roads to the proposed project sites with special attention given to critical periods in the life of wildlife (e.g. elk calving, migration routes, grouse strutting periods, raptor nesting periods, migratory bird breeding periods, etc.). Habitat management and creation should be directed toward encouraging the diversity of both game and non-game species, and should provide protection, rehabilitation, or improvement of wildlife habitat.

While no raptor nests were found during the 2015 surveys, if nests are discovered prior to development, the findings should be reported to CC&V Environmental Resources to ensure appropriate procedures are followed (CC&V 2013). It is prohibited to take a raptor, an active nest, eggs, or young under the federal Migratory Bird Treaty Act (and under the Bald and Golden Eagle Protection Act in the case of eagles). CPW has a set of recommended no surface occupancy buffer zones and seasonal human encroachment restrictions for active raptor nest sites (CPW 2008). The recommended buffer zones range from 1/4 mile to 1/2 mile depending on the species. Red-tailed hawks were observed in the project area and showed signs of territorial behavior (potentially indicated a nesting territory). CPW recommends a 1/3-mile non-disturbance buffer around active red-tailed hawk nests with no human encroachment from April to August. In addition, the presence of a juvenile great horned owl in the Chicago Portal area strongly suggests owl nesting in this area, possibly within one of the area's historic structures due to the paucity of large nest trees.

In addition to raptors, the Migratory Bird Treaty Act protects most other migratory bird species that could potentially occur in the project area. It is unlawful to destroy active nests of bird species listed under the Act. To minimize the potential for inadvertent nest destruction, vegetation clearing should be planned to take place outside of the active nesting season (approximately March 15 to July 15). If vegetation clearing must take place during the nesting season, a nest clearance survey could be conducted prior to construction to identify active nests so that they can be avoided.

5. SPECIAL STATUS SPECIES

ARCADIS queried USFWS, CDOW, and CNHP websites and developed a list of special status species that have potential to occur in the Amendment 11 Project area. Species and status designations are as follows:

Birds

- American peregrine falcon (*Falco peregrinus anatum*): state species of concern
- Bald eagle (*Haliaeetus leucocephalus*): state species of concern
- Burrowing owl (*Athene cunicularia*): state threatened
- Ferruginous Hawk (*Buteo regalis*): state species of concern
- Mexican spotted owl (*Strix occidentalis lucida)*: federally threatened/state threatened

Mammals

- Botta's pocket gopher (*Thomomy bottae rubidus*): state species of concern
- Preble's meadow jumping mouse (*Zapus hudsonius preblei*): federally threatened/state threatened
- Townsend's big-eared bat (*Corynorhinus townsendii palllescens*): state species of concern

Invertebrates

- Pawnee montane skipper (*Hesperia leonardus montana*): federally threatened

Plants

- Pale moonwort (*Botrychium pallidum*): state rare plant
- Reflected moonwort (*Botrychium echo*): state rare plant
- Rocky Mountain columbine (*Aquilegia saximontana*): state rare plant

5.1 Birds

5.1.1 American Peregrine Falcon

The American peregrine falcon is a state species of concern. This species inhabits open spaces usually associated with high cliffs and bluffs overlooking rivers or other large bodies of water (CPW 2011). No American peregrine falcons were observed in the Amendment 11 Project area. In addition, there is no suitable habitat (i.e., cliffs or high bluffs) for this species in the Amendment 11 Project area. Individuals of this species may occasionally pass through the area during migration but are not expected to stop over in the area due to the lack of suitable habitat.

5.1.2 Bald Eagle

In June 2007, the Secretary of the Interior announced the removal of the bald eagle from the federal threatened and endangered species list. However, bald eagles continue to be protected under the federal Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act.

Food availability is probably the single most important factor affecting bald eagle distribution and abundance. Fish and waterfowl are the primary sources of food. Big game and livestock carrion, as well as larger rodents (e.g. prairie dogs), also can be

important dietary components where these resources are available (Ehrlich et al. 1988).

There are no known bald eagle nest sites or winter roosts in the District or the Amendment 11 Project area. The project area lacks large water bodies that would support fish and waterfowl and other food resources in the project area are likely insufficient to attract bald eagles. Individuals of this species may occasionally pass through the area during migration but are not expected to stay in the area due to limited foraging habitat. No bald eagles were observed in the Amendment 11 Project area during the 2015 survey.

5.1.3 Burrowing Owl

The burrowing owl is a state listed threatened species. Burrowing owls occupy grasslands and mountain parks, typically in or near prairie dog colonies where they can use abandoned burrows to modify and use as their own (USFWS 2003). Limited grassland acreage and no prairie dog colonies were located within the Amendment 11 Project area during the 2015 survey. Though there are historic occurrences of this species within Teller County, current distribution maps do not show this species occupying Teller County (USFWS 2003). As such, it is not expected that burrowing owls would occur in the Amendment 11 Project area.

5.1.4 Ferruginous Hawk

The ferruginous hawk is a species of concern in Colorado. The ferruginous hawk is a bird of open grasslands and shrub steppe vegetation communities. These birds nest in flat, rolling, or rugged terrain in open areas, including short-grass prairie, canyons with cliffs or rock outcrops, and areas with isolated trees (Colorado Breeding Bird Atlas 1998). There is little suitable habitat for this species within native grasslands in the Amendment 11 Project area, and no ferruginous hawks or nests were observed during the 2015 survey. Considering this species typically avoids areas of high human disturbance (Colorado Breeding Bird Atlas 1998), such as mine activity and road work, the ferruginous hawk is unlikely to use habitats within the Amendment 11 Project area (particularly for nesting).

5.1.5 Mexican Spotted Owl

The Mexican spotted owl is a federally and state listed threatened species. It inhabits two different primary habitats in Colorado: 1) old growth mixed coniferous forests in mountainous areas at elevations ranging from 5,500 to 9,000 feet amsl and 2) areas of pinyon-juniper with scattered stands of old growth Douglas fir in steep, narrow, shady

canyons. Canyon bottoms often have riparian vegetation composed of cottonwoods (*Populus* spp.), willow (*Salix* spp.), box elder (*Acer negundo*), and other riparian shrub and tree species. Downed logs and snags are also important habitat components. Day roost sites are found in cool, shady canyons, often on north-facing slopes (Andrews and Righter 1992) or on ledges or in cavities in canyon walls (Ganey and Balda 1994).

Previous CNHP data (CNHP 1999) show recorded occurrences to the south, east, and north of the Amendment 11 Project area. The USFWS has designated three areas of critical habitat in Colorado. The closest critical habitat area is known as SRM-C-1a and encompasses areas to the south, east, and northeast of the Amendment 11 Project area (USFWS 2007).

Limited areas of potential foraging habitat for the Mexican spotted owl exist in the Amendment 11 Project area. However, no nesting habitat (old-growth forests, steep canyons) exists in the Amendment 11 Project area. Based on the limited size of observed foraging habitat patches and the distance from known critical habitat, Mexican spotted owls are not expected to occur in the Amendment 11 Project area.

5.2 Mammals

5.2.1 Botta's Pocket Gopher

The Botta's pocket gopher is a state species of concern. It can be found in a variety of vegetation types, including agricultural lands, grasslands, roadsides, open parklands, pinyon-juniper woodlands, open montane forests, and montane shrublands (NDIS 2011). Habitat, particularly in natural grassland and open conifer-dominated woodlands, is present within the Amendment 11 Project area. No individual Botta's pocket gophers were observed within the Amendment 11 Project area. However, burrow mounds distinctive of pocket gophers (plugged mounds) were observed in natural grasslands in the Amendment 11 Project area and the species is known to inhabit southern Teller County (Armstrong, et al. 2011).

5.2.2 Preble's Meadow Jumping Mouse

The Preble's meadow jumping mouse is a federally and state listed threatened species. Typical habitat for the Preble's meadow jumping mouse is composed of well-developed plains riparian vegetation with adjacent, relatively undisturbed grassland communities, and a nearby water source. These riparian areas include a relatively dense combination of grasses, forbs, and shrubs. This species is known to regularly range outward from riparian zones into adjacent uplands to feed and hibernate. The

project area lacks suitable riparian habitat for this species. The USFWS has designated 11 areas in Colorado as critical habitat (USFWS 2009). The closest critical habitat unit is Unit 10: Upper South Platte River. The unit consists of four subunits including one subunit (Trout Creek Subunit) which protrudes less than one mile into northern Teller County (USFWS 2009). This subunit is located approximately 40 miles north of the Amendment 11 Project area, and is not hydrologically connected to streams in the Amendment 11 Project area. Based on the lack of habitat in the Amendment 11 Project area and distance from mapped critical habitat, the Preble's meadow jumping mouse is not expected to occur in the Amendment 11 Project area.

5.2.3 Townsend's Big-Eared Bat

The Townsend's big-eared bat is a state species of concern in Colorado. This species can be found roosting in mines, caves, and other man-made structures in woodlands and forests to elevations above 9,500 feet amsl. Due to safety concerns, underground mine inspections were not conducted to determine the presence of bats in abandoned mines present within the Amendment 11 Project area. However, it is likely that bats, and potentially the Townsend's big-eared bat, occupy abandoned mine features in the Cresson Project area.

5.3 Invertebrates

5.3.1 Pawnee Montane Skipper

The Pawnee montane skipper is a federally listed threatened species. This butterfly inhabits dry, open ponderosa pine woodlands with a sparse understory at 6,000 feet to 7,500 feet amsl on soils derived from the Pikes Peak granite within the South Platte River drainage basin. Blue grama grass (*Bouteloua gracilis*) (the larval food plant) and prairie gayfeather (*Liatris spicata*) (the primary nectar plant) are two necessary components of the ground cover (USFWS 1998). The only known location for the Pawnee montane skipper is at Deckers, approximately 40 miles north of the Amendment 11 Project area (Ronish 1999). No potential habitat for the Pawnee montane skipper was observed in the Amendment 11 Project area. Small areas of ponderosa pine were observed with nearby blue grama, but no gayfeather was observed and the elevation was likely too high.

5.4 Plants

The pale moonwort, reflected moonwort, and Rocky Mountain columbine are all listed as state rare plants. Pale moonwort is known from east-central Teller County. Species habitat includes exposed hillsides, cleared areas including old mining sites at

elevations of 9,800 to 10,600 feet amsl (CNHP2014). The reflected moonwort occurs on rocky hillsides, and grassy slopes/meadows at elevations of 9,500 to 11, 000 feet amsl. Rocky Mountain columbine occurs on cliffs and rocky slopes at elevations of 9,000 to 12,300 feet amsl (CNHP 2014). The project area contains habitat patches for these species; however none of these special status plant species were observed in the Amendment 11 Project area during a habitat survey, and past survey data does not suggest the presence of these species in the Amendment 11 Project area.

5.5 Potential Impacts to Special Status Species

Potential burrows of the Botta's pocket gopher were found within open grassland habitat in Survey Area 1. This species is not afforded specific protections under state or federal laws; however, it is recommended that direct impacts to active burrows or colonies be avoided to the greatest extent feasible. Habitat management and creation should provide protection, rehabilitation, or improvement of habitat for this species as well as for all special status species with potential to occur in the Amendment 11 Project area.

The Townsend's big-eared bat can be sensitive to disturbance, particularly during hibernation. Therefore, if this species is ever identified in the Cresson Project area, care should be taken to not disturb it during the winter months to avoid accidental arousal during hibernation. Abandoned mine structures that could harbor roosting bats should be surveyed for the presence of bats prior to closure or removal.

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TABLES

Table 2-1 Soil Types in the Amendment 11 Project Area

Soil Map Unit (Component)	Survey Area 1 (acres)	Survey Area 2 (acres)	Total Acres
17. Catamount-Guffey complex, 15 to 40 percent slopes (Catamount)	--	29.6	29.6
17. Catamount-Guffey complex, 15 to 40 percent slopes (Guffey)	--	5.8	5.8
76. Disturbed land, mine areas, overburden storage areas, mine complex	39.4	3.2	42.6
79. Platdon loam, frequently flooded, 0 to 3 percent slopes	--	0.3	0.3
82. Quander-Bushpark very gravelly loams, 5 to 40 percent slopes (Bushpark)	54.0	--	54.0
82. Quander-Bushpark very gravelly loams, 5 to 40 percent slopes (Quander)	35.7	--	35.7
88. Rofork very gravelly sandy loam, 5 to 55 percent slopes	--	2.5	2.5
97. Seitz very gravelly loam, 20 to 50 percent slopes	15.1	--	15.1
Total	144.3	41.5	185.6

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Table 2-2 Amendment 11 Project Area Soil Characteristics

	17 – Catamount-Guffey Complex		79 - Platdon loam, frequently flooded	82 – Quander-Bushpark very gravelly loams		88 – Rofork very gravelly sandy loam	97 – Seitz very gravelly loam
	Catamount	Guffey		Quander	Bushpark		
Percentage of Map Unit*	60	30	90	60	30	90	90
Slope (%)	15-40	15-40	30-70	5-40	10-40	5-55	20-50
Aspect	All	All	All	All	All	Mostly south	Mostly north
Landforms	Mountainflank, mountaintop	Mountainflank, mountaintop	Floodplains	Mountainflank, mountainbase	Mountainflank, mountainbase	Mountainflank, mountaintop	Mountainflank
Parent Material	kind=slope alluvium over residuum source=granite	kind=colluvium over residuum source=granite	Alluvium	kind=colluvium source=phonolite, latite-phonolite, breccia from phonolite & latite, trachydolerite	kind=residuum source=phonolite, latite-phonolite, breccia from phonolite &latite, trachydolerite	kind=slope alluvium, residuum source=granite, gneiss	kind=colluvium, slope alluvium source= trachyte, breccias, tuff
Native Plant Community	Conifer-dominated Woodland	Mixed Conifer-Aspen Woodland	Wet Meadow	Natural Grassland	Natural Grassland, Aspen-dominated Woodland	Natural Grassland	Conifer-dominated Woodland
Typical Texture Profile	0 to 1” = decomposed plant material 1 to 3” = gravelly sandy loam 3 to 9” = very gravelly sandy loam 9 to 13” = extremely gravelly loamy coarse sand	0 to 1” decomposed plant material 1 to 13” = very gravelly coarse sandy loam 13 to 27” = very gravelly clay loam	0 to 18” = loam 18 to 30” = very gravelly sandy clay loam 30 to 60” = extremely gravelly sand	0 to 9" =gravelly loam 9 to 24" = very cobbly silty clay loam 24-60" = extremely cobbly silty clay loam	0 to 8” = fine gravelly silt loam 8 to 16” = fine gravelly silt loam 16 to 25” = very cobbly silt loam 25 to 30+” = extremely cobbly silty loam	0 to 5” = gravelly sandy loam 5 to 9” = extremely gravelly sandy loam 9 to 14” = extremely gravelly coarse sand	0 to 4” = conifer litter 4 to 16” = very gravelly loam to silt loam 18 to 26” = extremely cobbly silt loam 26+” = extremely cobbly silt loam
Depth Class	Very deep	Moderately Deep	Very Deep	Very deep	Shallow	Shallow	Very deep
Drainage Class	Excessively	Well	Poorly to Very Poorly	Well	Well	Well	Well
Organic Matter (%)	5	5	2	1	1	2	3
pH (standard units)	6.0	6.0	7.3	6.7	6.7	6.3	6.7
Salinity (mmhos/cm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Available Water Capacity (in/in)	0.06	0.06	0.05	0.03	0.03	0.05	0.04
Saturated Hydraulic Conductivity (µm/second)	16	16	216	12	12	24	22
NRCS Erosion Hazard (Off-Road, Off-Trail)	Moderate	Moderate	Severe	Moderate	Moderate	Moderate	Moderate

Notes:
* Remaining percentages of map units consist of contrasting inclusions.
Soil map unit 76 (Pits, mine-Dumps, mine complex) is not included due to lack of appreciable soils for reclamation salvage.
Site-specific data supplemented by NRCS soil survey data as applicable. Representative values (e.g., soil profile weighted average) for each soil unit component are provided.
Abbreviations: mmho/cm = millimho per centimeter; in/in = inch per inch; µm/second = micrometers per second

Table 2-3 Soil Salvage Depths and Suitability Ratings

Soil Map Unit - Component	Salvageable Depth (NRCS[1])	Salvageable Depth (This Study)		Suitability Rating - Observed	Suitability Rating - NRCS	Limiting Factors - Observed	Limiting Factors – NRCS[3]
		Range of Depth (inches)	Mean Depth (inches)				
17 - Catamount	9	NA	NA	Good to 9”	Poor	Coarse fragments; shallow bedrock	Droughty; shallow bedrock; low organic matter; acidity; sand content
17 – Guffey	27	22-26	24	Poor to 24”	Poor	Coarse fragments	Droughty; low organic matter; shallow bedrock; acidity
79 – Platdon	60	NA	NA	Good to 18” Fair to 30” Poor to 60”	Fair	Coarse fragments	Droughty; low organic matter
82 – Quander	60	>22 - >24	>23	Fair to 7” Poor to 60”	Poor	Coarse fragments; low organic matter	Cobble content; droughty; stone content; low organic matter
82 – Bushpark	16	9-21	16	Fair to 16”	Poor	Coarse fragments, low organic matter; shallow bedrock	Droughty; shallow bedrock
88 – Rofork	14	NA	NA	Poor to 14”	Poor	Shallow bedrock	Droughty; shallow bedrock; sand content; acidity
97 – Seitz	28	10-26	17	Fair to 14” Poor to 26”	Poor	Coarse fragments	Droughty; low organic matter; acidity; clay content

1 Based on review of NRCS 2014 data.
NA = no applicable field observations.
Source: NRCS Web Soil Survey, September 1, 2015.

Table 2-4 Soil Material Suitability Criteria for Salvage And Redistribution as Growth Medium

Soil Property	Soil Quality			
	Good	Fair	Poor	Unsuitable
Texture	Sandy loam Loam Silt loam	Sandy clay loam Silty clay loam Clay loam	Sandy clay Loamy sand Silty clay	Clay >60%
Coarse Fragment (gravel and larger) (% by volume)	0-25	25-50	>50	>50
Organic Matter (%)	>1.5	0.5-1.5	<0.5	--
Soil pH	6.1-7.8	5.1-6.1 7.9-8.4	4.5-5.0 8.5-9.0	<4.5 >9.1
Salinity (mmho/cm)	<3	3-6	6-9	>9
Available Water Retention Capacity (in/in)	>0.16	0.2-0.6	<0.2 or >6.0	--
Saturated Hydraulic Conductivity (µm/second)	10-100	1-10	<1 or >100	--

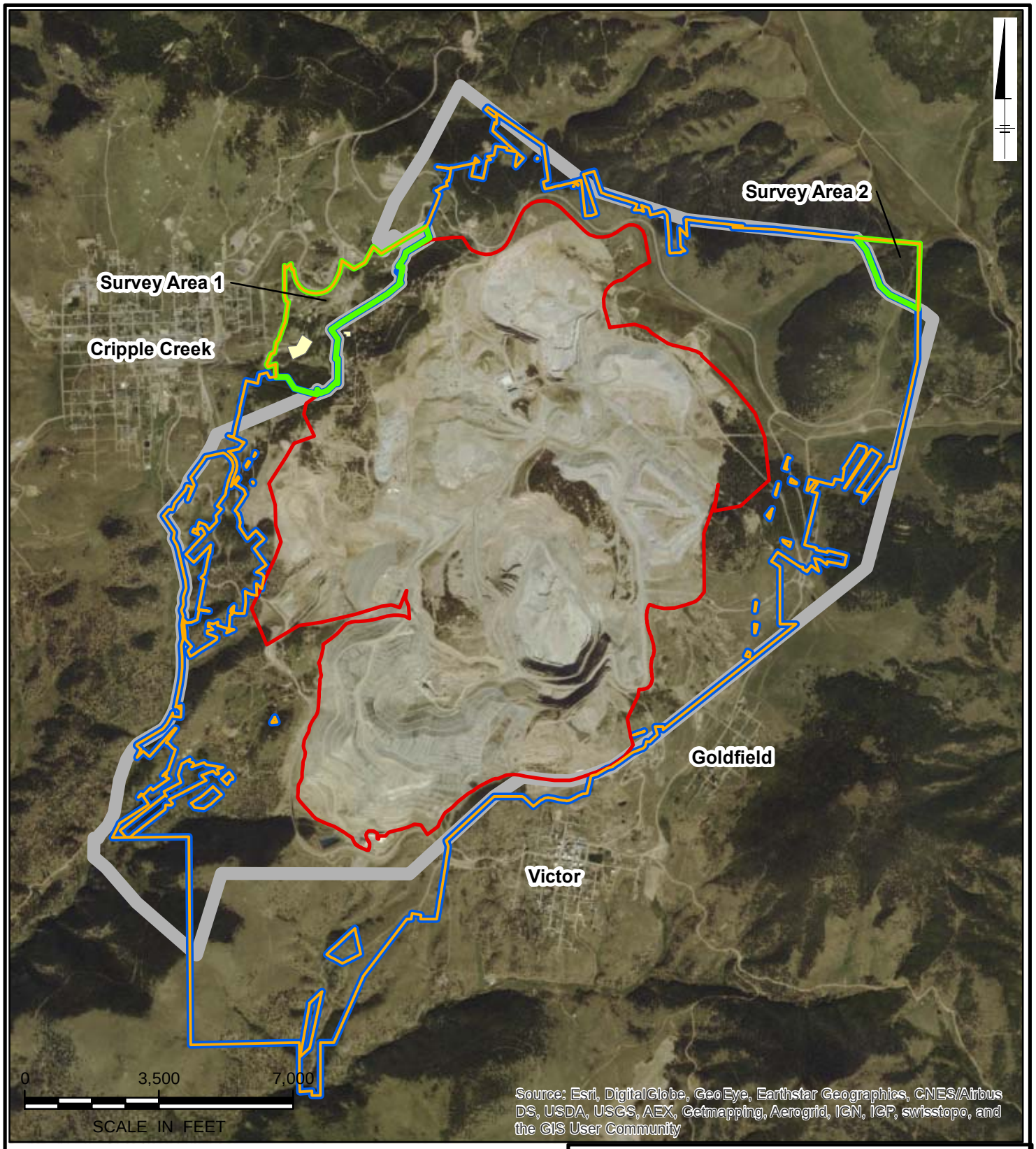
Notes:
Source: Modified from NRCS 1999
Abbreviations: mmho/cm = millimho per centimeter; in/in = inch per inch; µm/second = micrometers per second
Permeability classes have been replaced by Saturated Hydraulic Conductivity in current NRCS soil surveys. Correlative rating classes provided in NRCS Soil Survey Technical Note 6.
Soils considered to be unsuitable for reclamation if cobble content is greater than 50%.
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Table 3-1 Vegetation Community Type Acreage Summary in the Amendment 11 Project Area

Vegetation Community Type	Survey Area 1 (acres)	Survey Area 2 (acres)	Total Acres	Percent of Amendment 11 Project Area
Aspen-dominated woodland	63.1	--	63.1	34
Dense conifer-dominated woodland	--	36.5	36.5	20
Disturbed areas	46.8	3.2	50.0	27
Disturbed grassland	10.0	--	10.0	5
Mixed conifer/aspen-dominated woodland	15.1	--	15.1	8
Natural grassland	9.2	1.5	10.7	6
Wet meadow	--	0.3	0.3	<1
Riparian woodland	--	--	0	0
Total			**185.6**	**100**

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FIGURES



Legend

- Proposed Affected Land Boundary
- Amendment No. 11 Project Area
- Chicago Tunnel Permit Boundary
- Current Affected Land Boundary
- Amendment 10 Boundary
- Cripple Creek Mining Overlay District

M-1980-0244 AMENDMENT NO. 11 PROJECT
CRIPPLE CREEK MINING DISTRICT
TELLER COUNTY, COLORADO

PROJECT OVERVIEW MAP

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FIGURE
1

CITY:(DEN-TECH) DIV/GROUP:(ENV/GIS) DB: WEBB LD: PIC: PM: TM:
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Survey Area 1

Survey Area 2

82-Q
82-B
S1-4
S1-3
S1-5
97
76
82-Q
82-Q
S1-2
82-B
S1-6
S1-1
76
82-Q
82-Q
S1-7
S1-8
82-B

0 325 650
SCALE IN FEET

88
17-G
S3-3
S3-2
79
76
17-C
S3-1
76
88
S3-4
17-C
76

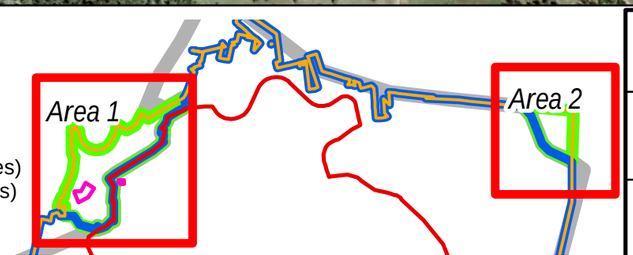
0 250 500
SCALE IN FEET

Legend

- Proposed Affected Land Boundary
- Chicago Tunnel Permit Boundary
- Current Affected Land Boundary
- Amendment 10 Boundary
- Amendment No. 11 Project Area
- Cripple Creek Mining Overlay District
- Soil Profile Location

Soil Map Units

- 17-C = Catamount-Guffey complex, 15 to 40 percent slopes (Catamount series)
- 17-G = Catamount-Guffey complex, 15 to 40 percent slopes (Guffey series)
- 76 = Disturbed land, mine areas, overburden storage areas, mine complex
- 79 = Platdon loam, frequently flooded, 0 to 3 percent slopes
- 82-B = Quander-Bushpark very gravelly loams, 5 to 40 percent slopes (Bushpark series)
- 82-Q = Quander-Bushpark very gravelly loams, 5 to 40 percent slopes (Quander series)
- 97 = Seitz very gravelly loam, 20 to 50 percent slopes
- 88 = Rofork very gravelly sandy loam, 5 to 55 percent slopes



M-1980-0244 AMENDMENT NO. 11 PROJECT
CRIPPLE CREEK MINING DISTRICT
TELLER COUNTY, COLORADO

SOIL MAP

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FIGURE
2

CITY:(DEN-TECH) DIV/GROUP:(ENV/GIS) DB: WEBB LD: PIC: PM: TM:
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Survey Area 1

Survey Area 2

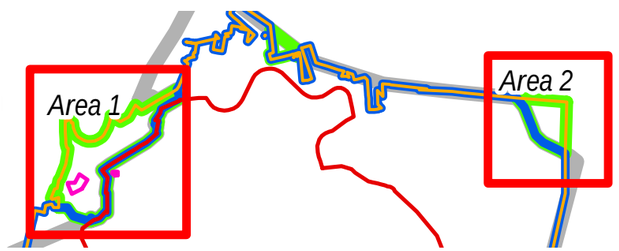
AD
DG
AD
MC
NG/D
NG
D
AD
AD
NG
AD
D
AD
AD
0 325 650
SCALE IN FEET

D
WM
DC
D
NG
DC
D
0 250 500
SCALE IN FEET

Legend

- Proposed Affected Land Boundary
- Chicago Tunnel Permit Boundary
- Current Affected Land Boundary
- Amendment 10 Boundary
- Cripple Creek Mining Overlay District
- Amendment No. 11 Project Area
- Plant Community

Plant Community Type
AD = Aspen Dominated
DC = Dense Conifer Dominated
D = Disturbed Areas
NG = Natural Grasslands
MC = Mixed Conifer - Aspen
WM = Wet Meadow
DG = Disturbed Grassland



M-1980-0244 AMENDMENT NO. 11 PROJECT
CRIPPLE CREEK MINING DISTRICT
TELLER COUNTY, COLORADO

PLANT COMMUNITY MAP

ARCADIS

FIGURE
3

CITY:(DEN-TECH) DIV/GROUP:(ENV/GIS) DB: WEBB LD: PIC: PM: TM:
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Appendix A

Vegetation Data

Table A-1 Plant Species Observed in Amendment 11 Project Area

Common Name	Scientific Name
TREES	
Subalpine fir	*Abies bifolia*
Rocky Mountain maple	*Acer glabrum*
Alder	*Alnus incana* ssp. *tenuifolia*
Englemann spruce	*Picea engelmannii*
Colorado blue spruce	*Picea pungens*
Bristlecone pine	*Pinus aristata*
Pinyon pine	*Pinus edulis*
Limber pine	*Pinus flexilis*
Ponderosa pine	*Pinus ponderosa*
Quaking aspen	*Populus tremuloides*
Douglas fir	*Pseudotsuga menziesii*
Gambel's oak	*Quercus gambelii*
Rocky Mountain juniper	*Sabina scopulorum*
SHRUBS	
Serviceberry	*Amelanchier alnifolia*
Bearberry	*Arctostaphylos uva-ursi*
Curl-leaf mountain mahogany	*Cercocarpus ledifolius*
Mountain mahogany	*Cercocarpus montanus*
Green rabbitbrush	*Chrysothamnus viscidiflorus*
Hazelnut	*Corylus cornuta*
Oceanspray	*Holodiscus discolor*
Common juniper	*Juniperus communis*
Prickly pear cactus	*Opuntia polyacantha*
Boulder raspberry	*Oreobatus deliciosus*
Shrubby cinquefoil	*Pentaphylloides floribunda*
Gooseberry current	*Ribes cereum*
Wild current	*Ribes inerme*
Wild gooseberry	*Ribes montigenum*
Wood rose	*Rosa woodsii*
Thimbleberry	*Rubacer parviflorum*
Red raspberry	*Rubus idaeus* ssp. *melanolasius*
Red elderberry	*Sambucus microbotrys*
Dwarf bilberry	*Vaccinium cespitosum*
Spanish bayonet	*Yucca glauca*
FORBS	
Yarrow	*Achillea millefolium*
Blue flax	*Linum lewisii*
False dandelion	*Agoseris glauca*
Wild onion	*Allium cernuum*
Pussytoes	*Antennaria rosea*
Arnica	*Arnica* sp.
Fringed sage	*Artemisia frigida*
Mugwort	*Artemisia ludoviciana*
Leafy aster	*Aster foliaceus*
Milk vetch	*Astragalus* sp.
Blue clematis	*Atragene columbiana*
Kochia	*Bassia sieversiana*
Bistort	*Bistorta bistortoides*

Table A-1 Plant Species Observed in Amendment 11 Project Area

Common Name	Scientific Name
False arabis	*Boechera* sp.
Canada thistle	*Breea arvensis*
Gunnison star-tulip	*Calochortus gunnisonii*
Common harebell	*Campanula rotundifolia*
Whitetop	*Cardaria chalepensis*
Musk thistle	*Carduus nutans*
Indian paintbrush	*Castilleja miniata*
Indian paintbrush	*Castilleja rhexifolia*
Fireweed	*Chamerion danielsii*
Canada thistle	*Cirsium arvense*
Colorado thistle	*Cirsium scariosum*
Bull thistle	*Cirsium vulgare*
Rocky Mountain beeplant	*Cleome serrrulata*
Brittle fern	*Cystopteris fragilis*
Fleabane	*Erigeron* sp.
Wild buckwheat	*Eriogonum umbellatum*
Wild strawberry	*Fragaria virginiana*
Monument plant	*Frasera speciosa*
Bedstraw	*Galium septentrionale*
Wild geranium	*Geranium caespitosum*
Gumweed	*Grindelia squarrosa*
Golden aster	*Heterotheca villosa*
Alum-root	*Huechera parvifolia*
Wild iris	*Iris missouriensis*
Ox-eye daisy	*Leucanthemum vulgare*
Nodding ragwort	*Ligularia bigelovii*
Dalmation toadflax	*Linaria genistifolia* ssp. *dalmatica*
Yellow toadflax	*Linaria vulgaris*
Tansy aster	*Machaeranthera canescens*
Moss	mosses
Mushroom	mushrooms
Evening primrose	*Oenothera elata*
Cat's-eye	*Oreocarya thyrsiflora*
Owl clover	*Orthocarpus luteus*
Canada lousewort	*Pedicularis canadensis*
Fern lousewort	*Pedicularis procera*
Red beardtongue	*Penstemon barbatus*
Beardtongue	*Penstemon virgatus*
Bottle gentian	*Pneumonanthe parryi*
Cinquefoil	*Potentilla ovina*
Cinquefoil	*Potentilla pulcherrima*
Tuber starwort	*Pseudostellaria jamesiana*
Black-eyed susan	*Rudbeckia ampla*
Dock	*Rumex* sp.
Figwort	*Scrophularia lanceolata*
Jim Hill mustard	*Sisymbrium altissimum*
Blue-eyed grass	*Sisyrinchium montanum*
Cut-leaf Tansy	*Tanacetum vulgare*
Dandelion	*Taraxacum officinale*

Table A-1 Plant Species Observed in Amendment 11 Project Area

Common Name	Scientific Name
Meadowrue	*Thalictrum fendleri*
Golden banner	*Thermopsis Montana*
Pennycress	*Thlaspi arvense*
Salsify	*Tragopogon dubius*
Salsify	*Tragopogon pratensis*
Clover	*Trifolium* sp.
Stinging nettle	*Urtica gracilis*
Mullein	*Verbascum thapsus*
GRAMINOIDS	
Indian ricegrass	*Achnatherum hymenoides*
Letterman's needlegrass	*Achnatherum lettermanii*
Bentgrass	*Agrostis scabra*
Redtop	*Agrostis stolonifera*
Cheatgrass	*Bromus tectorum*
Pine dropseed	*Blepharoneuron tricholepis*
Mountain brome	*Bromopsis canadensis*
Smooth brome	*Bromus inermis*
Sedge	*Carex athrostachya*
Sedge	*Carex filifolia*
Elk sedge	*Carex geyeri*
Nebraska sedge	*Carex nebrascensis*
Sedge	*Carex simulata*
Sedge	*Carex utriculata*
Sedge	*Carex vesicaria*
Blue grama	*Chondrosum gracile*
Foxtail barley	*Critesion brachyantherum*
Parry's oatgrass	*Danthonia parryi*
Tifted hairgrass	*Deschampsia caespitosa*
Squirrel tail	*Elymus elymoides*
Blue wild-rye	*Elymus glaucus*
Thickspike wheatgrass	*Elymus lanceolatus*
Bearded wheatgrass	*Elymus trachycaulus* ssp. *subsecundus*
Slender wheatgrass	*Elymus trachycaulus* ssp. *trachycaulus*
Arizona fescue	*Festuca arizonica*
Idaho fescue	*Festuca idahoensis*
Baltic rush	*Juncus balticus*
Junegrass	*Koelaria macrantha*
Mountain muhly	*Muhlenbergia montana*
Green needlegrass	*Nassella viridula*
Western wheatgrass	*Pascopyrum smithii*
Kentucky bluegrass	*Poa pratensis*
Bluegrass	*Poa secunda*
Bluebunch wheatgrass	*Pseudoroegnaria spicata*
Intermediate wheatgrass	*Thinopyrum intermedium*
Spike trisetum	*Trisetum spicatum*

Taxonomic names conform to Weber and Wittman (1996)

Table A-2 Plant Species by Vegetation Types in the Amendment 11 Project Area

Typical Plant Species	Abundant	Common	Occasional
Aspen-dominated Woodland			
Trees	*Populus tremuloides*	*Picea engelmannii*	*Abies lasiocarpa*
		Pinus flexilis	*Picea pungens*
			Pinus contorta
			Pinus ponderosa
			Pseudotsuga menziesii
Shrubs	Not observed		
Forbs	*Thermopsis montana*	*Achillea lanulosa*	*Aquilegea coerulea*
		Astragalus sp.	*Campanula rotundifolia*
		Chamerion danielsii	*Maianthemum racemosum*
		Thalictrum fendleri	*Senecio sp.*
		Potentilla ovina	
		Trifolium sp.	
Graminoids		*Bromus ciliatus*	
		Elymus glaucus	
		Elymus trachycaulus	
		Festuca arizonica	
Dense, Conifer-dominated Woodland			
Trees	*Pinus contorta*	*Picea engelmannii*	*Picea pungens*
	Populus tremuloides	*Pinus flexilis*	
Shrubs	*Juniperus communis*	*Arctostaphylos uva-ursi*	
		Vaccinium spp	
Forbs	*Thermopsis montana*	*Erigeron* sp.	*Dasiphora [Pentaphyloides] floribunda*
			Astragalus sp.
			Achillea millefolium
			Aquilegea sp.
			Geranium caespitosum
			Campanula rotundifolia
Graminoids	Not observed		
Mixed Conifer/Aspen-Dominated Forest			
Trees	*Populus tremuloides*	*Pinus flexilis*	
	Picea engelmannii		
Shrubs		*Vaccinium sp.*	*Dasiphora floribunda*
Forbs	*Thermopsis montana*	*Fragaria virginiana*	*Astragalus sp.*
		Muhlenbergia montana	*Erigeron sp.*
Graminoids		*Bromus ciliatus*	

Table A-2 Plant Species by Vegetation Types in the Amendment 11 Project Area

Typical Plant Species	Abundant	Common	Occasional
Disturbed Areas			
Trees		*Populus tremuloides*	*Pinus ponderosa*
Shrubs			*Dasiphora floribunda*
Forbs	Not observed		
Graminoids		*Danthonia parryii*	*Bromus tectorum*
		Muhlenburgia montana	
Natural Grassland			
Trees			*Populus tremuloides*
Shrubs	Not observed		
Forbs	*Antennaria sp.*		*Artemisia frigida*
			Achillea millefolium
			Cirsium scopularum
Graminoids	*Danthonia parryi*	*Carex oreocharis*	
	Koelaria macrantha	*Bromopsis ciliata*	
	Poa pratensis		
	Muhlenbergia montana		
	Elymus elymoides		
	Pascopyron smithii		
	Elymus trachycaulus ssp. *Subsecundus*		
	Festuca arizonica		
Disturbed Grassland			
Trees	Not observed		
Shrubs	Not observed		
Forbs		*Cirsium arvense*	
		Cirsium vulgare	
		Linaria dalmatica	
Graminoids	*Poa pratensis*	*Elymus elymoides*	
	Pascopyrum smithii	*Agrostis stolonifera*	
		Koelaria macrantha	
		Nassella viridula	
		Festuca arizonica	
		Bromus inermus	
Riparian Woodland – Not observed in Project area, but if it did occur, plants may include:			
Trees	*Picea pungens*	*Sabina scopulorum*	
	Populus tremuloides	*Acer glabrum*	

Table A-2 Plant Species by Vegetation Types in the Amendment 11 Project Area

Typical Plant Species	Abundant	Common	Occasional
	Pinus ponderosa	*Pinus aristata*	
	Alnus incana		
	Pseudotsuga menziesii		
	Picea engelmannii		
Shrubs		*Holodiscus dumosus*	
		Ribes inerme	
		Ribes montigenum	
		Ribes cereum	
		Rubacer parviflorum	
Forbs	*Linaria vulgaris*	*Achillea lanulosa*	
		Cystopteris fragilis	
		Bassia sieversiana	
		Thalictrum fendleri	
		Carduus nutans	
		Artemisia frigida	
		Penstemon virgatus	
		Cleome serrulata	
		Tanacetum vulgare	
Graminoids	*Elymus lanceolatus*	*Achnatherum lettermanii*	
	Poa pratensis	*Agrostis stolonifera*	
	Muhlenbergia montana	*Bromus canadensis*	
	Nasella viridula	*Elymus trachycaulus* ssp. *subsecundus*	
		Chondrosum gracile	
		Elymus trachycaulus ssp. *subsecundus*	
Wet Meadow			
Trees	Not observed		
Shrubs	Not observed		
Forbs		*Caltha leptosepala*	
		Iris missouriensis	
		Ranunculus spp.	
Graminoids		*Carex spp.*	
		Deschampsia caespitosa	
		Potentilla ovina	
		Eleocharis spp.	

Table A-2 Plant Species by Vegetation Types in the Amendment 11 Project Area

Typical Plant Species	Abundant	Common	Occasional
		Juncus balticus	

Taxonomic names conform to Weber and Wittman (1996)

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November 3, 2015

Mr. Gary Horton
Cripple Creek & Victor Gold
Newmont Mining Corporation
P. O. Box 191
Victor, CO 80860

Re: Review of Blasting Studies at CC&V

Dear Mr. Horton:

Matheson Mining Consultants, Inc. (MMC) has reviewed the seven Ground Motion Attenuation Studies that Vibra-Tech Engineers, Inc. and Matheson Mining Consultants, Inc. have performed since 1997 for Cripple Creek and Victor Gold Mining Company to assess the potential impacts to ground motion from the proposed underground exploration and mining that will be added as part of Amendment 11. Each of these studies was measurement of surface blasting in varying locations on the property. Below is a Table with the results of the seven studies.

Date	Location	H	Beta	R squared
6/13/97	Ajax	261	-1.62	0.889
6/13/97	Ridge Road	286	-1.80	0.921
11/26/97	Leach Pad	11	-1.19	0.704
2/25/00	N. Cresson	168.6	-1.54	0.913
3/5/04	E. Cresson	313.3	-1.825	0.894
3/5/04	E. Cresson	19.89	-1.059	0.804
3/5/04	E. Cresson	21.89	-1.096	0.788

Each of the above fits to the formula:

$$PPV = H(SD)^{-B}$$

Where, H = the velocity (y axis intercept) at a scaled distance of one,
B = the slope of the curve,
PPV = the peak particle velocity in inches per second, and
SD = scaled distance = distance (feet) from shot to recorder divided by the square root of the charge weight (pounds)

The program also yields the correlation coefficient (goodness of fit), 1.0 is perfect.

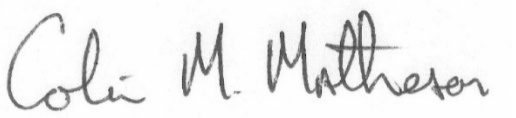
Proposed underground mining activity is not expected to contribute an increase in ground motion over what is already expected with current surface mining activities. The charge weights per delay period in surface blasting are of a larger size than typical underground blasting. The energy released in surface blasting creates surface waves that radiate concentrically from the energy source. Underground blasting typically results in lower surface wave amplitudes as the path from the energy source along surfaces is much longer. The energy released in an underground blast attenuates significantly before the wave train arrives at the surface. The concern in underground blasting is usually limited to the effects on ground stability in the immediate vicinity of the energy release, e.g. the effect on stope pillars.

MMC recommends confirmation of the relatively low vibrations created in underground blasting by measurement with calibrated seismographs once the underground blasting commences. If underground blasting is forecast to approach adjacent underground workings it would be prudent to measure the ground motion at these adjacent locations.

Blasting creates a range of seismic affects, the most important of which are surface waves and how they impact other surface facilities. Underground blasting creates very modest amounts of surface waves especially when compared to open pit production blasting.

MMC will be pleased to verify these statements once underground blasting commences.

Sincerely,



Colin M. Matheson,
President, Matheson Mining Consultants, Inc.

GEOTECHNICAL SLOPE RECOMMENDATIONS

FOR THE NORTH AREA UNDERGROUND MINING AREAS

Prepared for

CRIPPLE CREEK & VICTOR GOLD MINING COMPANY

By

S. D. Cylwik

R. C. Barkley

November 2015

CALL & NICHOLAS, INC.

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1.0 EXECUTIVE SUMMARY

As requested by the Cripple Creek & Victor Gold Mining Company (CCV), Call & Nicholas, Inc. (CNI) performed a geotechnical slope design study for the mining areas associated with the North Area Underground (NAU) and Amendment 11 permitting activities. The purposes of the study were: (1) to determine optimum interramp slope angles and bench design parameters for the NAU mine areas designs, (2) to identify and analyze any potential major instability that would represent a significant cost to or interference with the mine operations, and (3) provide recommendations for slope management over the life of the project.

Analytical stability analyses included: (1) bench-scale back break analysis from which the expected distribution of bench-face angles (BFA) and reliability schedules were developed, and (2) global wall stability associated with long release structures and weak rock mass. The back break analysis relied on cell-mapping conducted along existing mine benches in the Wild Horse Extension (WHEX) portion of the North Cresson mining areas. The global stability analyses were performed using rock strength data and drilling data to characterize the rock mass and to estimate the shear strength of the rock mass in relation to the excavation induced stresses.

1.1 Recommended Interramp Slope Angles for the NAU Designs

Figure 1-1 and Table 1-1 report the recommended interramp slope angles resulting from the analyses listed above. The table indicates the stability analysis that controlled the slope angle for each design sector and the recommended mining increment (single or double).

The recommendations listed in the figure and table apply only to hard rock. Any dumps, fill, colluvium, alluvium, or near surface highly weathered rock that is encountered should be excavated at a smooth wall slope angle of 34 degrees.

1.1.1 Sector 1: North-Dipping Walls in Precambrian Schist

Sector 1 should not be mined at an angle steeper than 30 degrees to avoid daylighting foliation in the Precambrian schist. Foliation structures in the schist are expected to dip to the north-northwest at 25 to 45 degrees for both the WHEX and Schist Island areas of sector 1. The foliation structures have a measured friction angle of 20.1 degrees, and therefore the interramp slope angle should not exceed the minimum expected dip of the foliation in order to avoid progressive style slope instability.

A regressive type slope instability is still possible at an interramp angle of 30 degrees in sector 1. However, if the slope is mined at an interramp angle of 30 degrees and is properly monitored and managed, it presents little risk to personnel or equipment due to its relatively shallow slope.

1.1.2 Sectors 4, 5, 6, 7, and 9: Globe Hill Pipe Zone

Maximum slope angles in sectors 4, 5, 6, 7, and 9 are controlled by global stability and the shear strength of the Globe Hill pipe rock zone. The Globe Hill pipe is a shattered and altered zone located in the central and southern portions of the Globe Hill mine. The pipe is highly fractured with a rock quality designation (RQD) typically less than 5 percent. Single benching has been recommended for these sectors. Double benching may be possible, but the effects of production blasting on the Globe Hill pipe must first be observed since the rock will be easily disturbed. A design chart has been created for slopes excavated within the Globe Hill pipe, which is presented in Chapter 6.

1.1.3 Catch-Bench Width Controlled Sectors

The recommended interramp angles for all other sectors are controlled by the bench-scale analysis that determines the optimum angle required to maintain adequate catch bench widths. These recommendations assume that the benches will be excavated to a double bench height of 70 feet and that pre-split blasting will be performed. Slopes should be designed and excavated to the mean catch-bench widths and bench-face angles listed in Table 1-1. After excavation, back break along the bench crests will reduce the catch-bench widths to the required 80 percent reliability of achieving 26 feet for double benching. A mid-bench offset of 8 feet was assumed for double benching based on previous experience at Cripple Creek. If the offset created between benches during mining is greater than 8 feet, inadequate catch-bench widths will be achieved. The offset can be completely avoided by drilling the pre-split row the full double bench height in a single pass.

Additionally, increasing the interramp slope angles beyond the recommended angles increases the potential for interramp failures along daylighted faults. Careful slope monitoring, including up-to-date mine area mapping and interpretation of major structures, will be required

to identify zones of potential instability and to aid in the placement of slope monitoring equipment including prisms, extensometers, and slope radar.

1.2 Upside Potential to Recommended Slope Angles

1.2.1 Foliation in Schist Island Portion of Sector 1

The slope in the Schist Island portion of Sector 1 is controlled by foliation that is expected to dip towards the excavation at 25 to 45 degrees. This assumption is based on a geotechnical televiewer hole (CPC14-1) that was drilled approximately 1300 feet away from the slope under investigation. There have been no core holes drilled directly though the south Schist Island slope in Sector 1. If a televiewer core hole were to be drilled and demonstrate that either the slope is not comprised of schist or that the foliation in the schist is not dipping towards the north, the design interramp slope angle would be greatly increased. The recommendation for an additional televiewer hole is presented in Figure 1-2.

1.2.2 Additional Drilling in the Globe Hill Area

Very little geotechnical drill data exists behind the designed slopes for the west and southeast walls of the Globe Hill mine. These slopes were assumed to be comprised of the weak Globe Hill pipe rock mass based on interpolation from nearby drill holes. CNI recommends that additional drilling be performed to obtain geotechnical data behind the designed slopes. If drilling can demonstrate competent rock mass in these zones, steeper design interramp angles would result. Recommended locations for additional geotechnical drilling in the Globe Hill area are shown in Figure 1-2.

1.2.3 Globe Hill Pipe Shear Strength

The Globe Hill pipe altered zone shear strength was estimated based on previous experience in similar type materials. It is very difficult (if not impossible) to directly measure the shear strength of a lightly cemented, interlocked, non-plastic gravel such as the Globe Hill pipe; the material cannot be tested in a large-scale direct-shear or triaxial cell because the particle size is too large, and the material cannot be sampled or cored without disturbing it and breaking up the particle interlock. It is possible that the Globe Hill pipe material may perform better than expected when excavated in the Globe Hill mine. The observational method combined with

diligent monitoring and bench design reconciliation will reveal how the material performs under actual field conditions, and whether an increase in slope angle is justified.

1.2.4 Catch-Bench Width Controlled Sectors

Because the bottom of the second bench is not typically shot with a pre-split hole it is common to encounter hard toe at the base of double benches at CCV. If the hard toe can be completely eliminated (either by manual excavation with a top-hammer pick or by utilizing full 70-foot pre-splits) an 8-foot offset would not be needed in the bench-scale analysis of double benches and steeper achievable double-bench interramp angles would result.

1.2.5 Catch-Bench Width Performance Reconciliation

Optical scans of the constructed bench face angles may be performed to evaluate catch-bench width performance. If performance of benches is shown to be better than predicted in the bench-scale analyses, interramp slope angles may accordingly be increased. These data may also be used to calibrate future bench-scale analysis at CCV.

1.2.6 Schist vs. Gneiss in Precambrian Rock Type

In the CCV geology block model the Precambrian rock type is not differentiated into its various lithology types. As a consequence of this, all sectors in the Precambrian were assumed to have the joint shear strengths of schist, which is the most conservative assumption. This is the lowest joint shear strength tested of any rock type. If gneiss is exposed in sectors 1 through 7 the results of the bench-scale analyses may be conservative in these areas.

1.3 Additional Recommendations

1.3.1 Blasting in Globe Hill Pipe Zone

Judicious blasting practices will be required when mining in the Globe Hill pipe zone as the rock will be easily disturbed. If the benches are disturbed by blasting, it will be difficult to achieve bench face angles steeper than 37 degrees. Drop cuts should not be performed near the final walls. Lightly loaded pre-split holes shot before the production blast and trim shots of no less than four rows should be utilized to protect the final wall from damage.

1.3.2 Surface Water Control in Globe Hill Pipe Zone

The Globe Hill pipe material will be easily eroded by flowing surface water. Catch benches should be sloped back into the wall at an angle of approximately 3 degrees to discourage flow of water across the bench faces. Catch benches should be laterally sloped so that surface water will flow out of the zone onto more competent rock.

1.3.3 Piezometer Installation in Globe Hill Pipe Zone

The stability of the slopes within the Globe Hill pipe will be very sensitive to pore water pressures. For the global stability analysis (Chapter 6) all slopes were assumed to be fully drained and depressurized. Piezometers should be installed in the central portion of the Globe Hill pipe prior to mining in order to verify that there are no pore pressures within the pipe. The recommended location for piezometer installation is shown in Figure 1-2.

1.3.4 Underground Void Mitigation

Due to the long history of underground mining in the Cripple Creek district, historic voids may need to be mined through in the NAU area. Underground voids present a risk for personnel operating on the pit bottom above them. The greatest risk is that of a crown pillar failure while personnel are working above. The best mitigation strategy is to identify voids before the crown pillar is mined through, and to drill and blast the crown pillars before they become too thin and unstable. At CCV crown pillars above voids are typically blasted once the factor of safety is below 1.20. Once the stopes are opened and exposed to the surface, they should be completely backfilled.

A standardized workflow has been developed to simply the process of estimating the Q' parameter required to evaluate the factor of safety of a crown pillar above a void. This workflow is shown in Figure 1-3. The suggested relation between factor of safety and probability of failure is shown in Figure 1-4.

1.4 Future Work

Slope design is an iterative process; optimum slope design requires continuous effort to collect, interpret, and analyze geologic and geotechnical data as they become available.

Data for the Globe Hill and Schist Island portions of the North Cresson mining area was pulled from previous cell and major structure mapping campaigns in the WHEX mining area. These rock-fabric and major structure data were assumed for the new NAU mining areas, and can therefore only be considered as "inferred" data. As mining begins on benches in the NAU mining areas, follow-up cell mapping and bench-face geologic mapping should be performed along new benches to confirm the assumed data. Mapping is required to:

1. Confirm fracture characteristics and design parameters recommended in this study
2. Determine the upside potential in the recommended slope design
3. Detect any potential instability problems in a timely way

CNI recommends an ongoing program of data collection and re-evaluation. *Appendix A*: *Slope Monitoring and Management* discusses specific components required to optimize the mine plan while maintaining safe operating conditions in the mine.

Mining area mapping should focus on:

1. Identifying multibench-length major structures, especially those that may adversely impact stability
2. Locating water seeps
3. Identifying continuous zones of low rock-mass strength
4. Recording evidence for possible slope movement such as tension cracks, toe heaves, or recent movement along structures

The geological, structural, and geotechnical data should also be compiled routinely. A composite geology and structure map should be updated at least once a year. Periodic BFA surveys should be conducted along benches to evaluate the success in achieving the bench geometries and interramp angle recommendations.

1.4.1 Surface/Underground Mine Interaction

At the time of this report underground mine designs had not yet been completed for the NAU study area. Once the initial underground designs are ready, but before construction begins, a geotechnical evaluation should be performed to investigate the possibility of interaction between the surface and underground operations.

1.4.2 Pre-split Blasting on Final Wall

CNI recommends that CCV continue implementing pre-split blasting, especially on the final walls. Pre-split holes drilled to the full double bench height of 70 feet will improve the reliability of the benches by increasing the bench face angle. More information about pre-split and other controlled blasting methods is presented in *Appendix B: Controlled Blasting*.

In addition to constructing clean, well-cut bench faces, the reliability of catch benches can be improved by ensuring the toes of each mining increment are cleaned before proceeding with the next increment. CCV is generally very good with this practice. Leaving material that can be easily cleaned is not good practice because it reduces the capacity of the bench to catch falling rock and also interferes with the drill's ability to reach the toe of the current bench.

1.4.3 Slope Monitoring

Any major slope failure along mining area walls could disrupt mining activity; therefore, a slope monitoring program is recommended at Cripple Creek. The program should include the following:

1. Periodic reconnaissance mapping should be conducted to identify areas of potential instability.
2. Prisms should be placed throughout the mine and wireline extensometers be installed at areas of potential instability.
3. Benches (particularly those above critical access haul roads or mine installations) should be periodically inspected where slope instability would have the greatest operational and financial impact.

Using pertinent data collected from routine mining area mapping and ongoing geotechnical programs, monthly reports with accompanying maps should be published and circulated to key mining personnel. Contingency plans that allow for alternative mining schemes should be developed in case of slope instability at critical locations.

1.4.4 Hydrology

CNI recommends conducting the following groundwater-related work at Cripple Creek:

1. Water seeps along mining area walls should be documented and seasonal fluctuations, if any, should be recorded. This information can be collected during routine mining area mapping.
2. Records should be kept on blasthole water depths if encountered.

3. Piezometers should be installed at strategic locations along the final wall to define the possible influence perched groundwater and its fluctuations may have on slope stability.

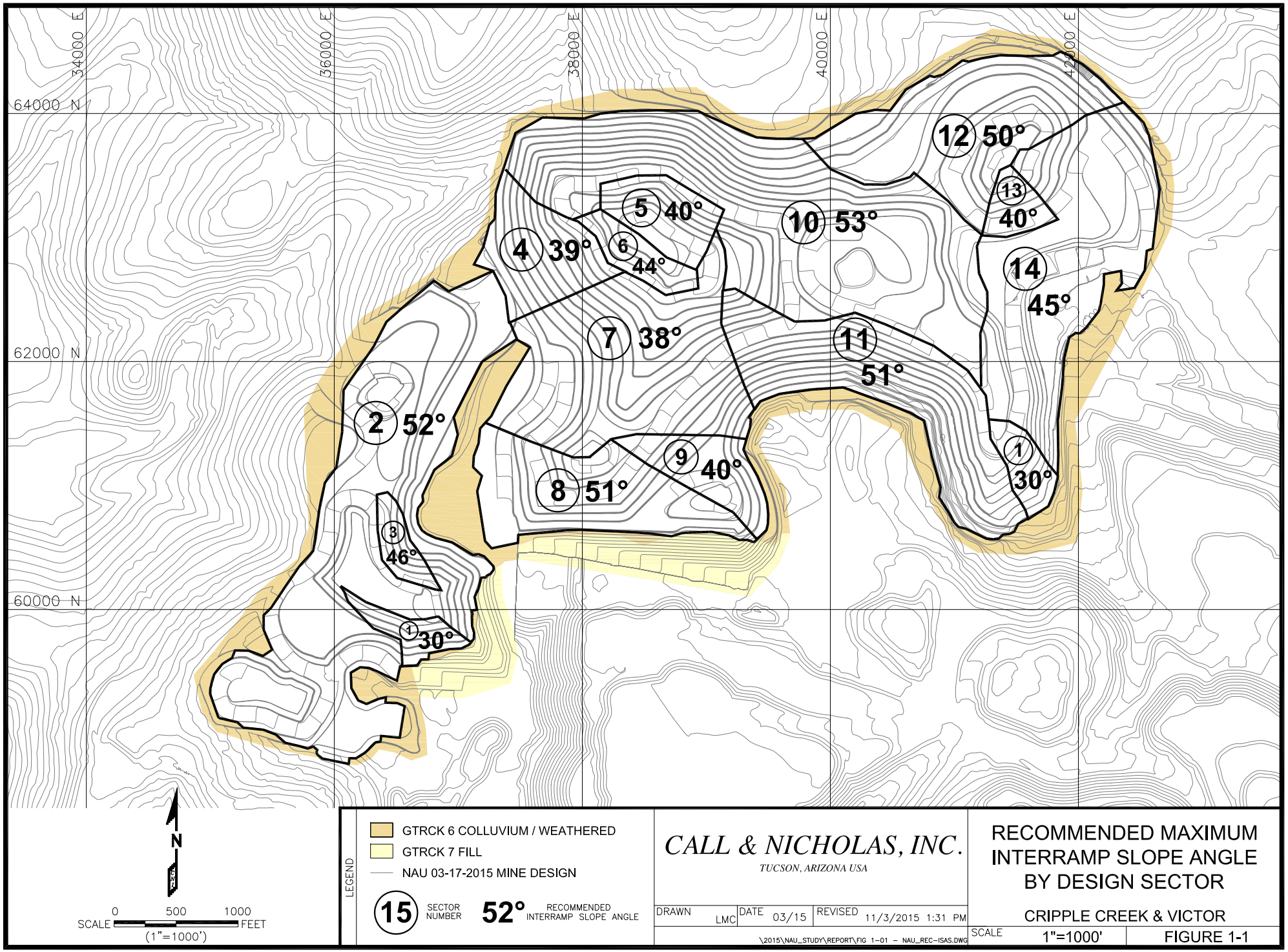
Table 1-1. Recommended Interramp Slope Angles

Design Sector	Recommended Interramp Slope Angle	Mining Area	Design Control	Design Parameters[1,2]			Comments
				Bench (S/D)	Mean Catch-Bench Width (ft)	Mean Bench-Face Angle	
1	**30°**	WHEX and Schhist Island portion of North Cresson	Global	S	40.4	60°	Foliation Dips Towards Excavation
2	**52°**	Schist Island portion of North Cresson	Bench	D	34.6	74°	
3	**46°**	Schist Island portion of North Cresson	Bench	D	43.5	71°	
4	**39°**	Globe Hill portion of North Cresson	Global	S	23.0	60°	Weak Globe Hill Pipe Zone
5	**40°**	Globe Hill portion of North Cresson	Global	S	21.5	60°	Weak Globe Hill Pipe Zone
6	**44°**	Globe Hill portion of North Cresson	Global	S	19.9	65°	Weak Globe Hill Pipe Zone
7	**38°**	Globe Hill portion of North Cresson	Global	S	24.6	60°	Weak Globe Hill Pipe Zone
8	**51°**	Globe Hill portion of North Cresson	Bench	D	35.3	73°	
9	**40°**	Globe Hill portion of North Cresson	Global	S	21.5	60°	Weak Globe Hill Pipe Zone
10	**53°**	Globe Hill and WHEX portion of North Cresson	Bench	D	37.9	78°	
11	**51°**	Globe Hill and WHEX portion of North Cresson	Bench	D	37.9	75°	
12	**50°**	WHEX portion of North Cresson	Bench	D	40.0	75°	
13	**40°**	WHEX portion of North Cresson	Bench	D	57.9	70°	
14	**45°**	WHEX portion of North Cresson	Bench	D	44.5	70°	

1. Slopes should be designed and excavated to the mean catch-bench widths and bench-face angles listed above. After excavation, back break along the bench crests will reduce the catch-bench widths to the required 80 percent reliability of achieving 26 feet for double benching and 19 feet for single benching for sectors controlled by back break.

2. A mid-bench offset of 8 feet was assumed for double benching based on previous experience at Cripple Creek. If the offset created between benches during mining is greater than 8 feet, inadequate catch-bench widths will be achieved. The offset can be completely avoided by drilling the pre-split row the full double bench height in a single pass.

3. Slopes mined in dump, fill, colluvium, or weathered material should be mined at a continuous 34° slope.


34000 E
36000 E
38000 E
40000 E
42000 E
64000 N
62000 N
60000 N
12 50°
13 40°
5 40°
10 53°
4 39°
6 44°
14 45°
7 38°
11 51°
2 52°
9 40°
1 30°
8 51°
3 46°
1 30°
N
0 500 1000
SCALE FEET
(1"=1000')
LEGEND
GTRCK 6 COLLUVIUM / WEATHERED
GTRCK 7 FILL
NAU 03-17-2015 MINE DESIGN
15 SECTOR NUMBER
52° RECOMMENDED INTERRAMP SLOPE ANGLE
CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA
DRAWN LMC
DATE 03/15
REVISED 11/3/2015 1:31 PM
\2015\NAU_STUDY\REPORT\FIG 1-01 - NAU_REC-ISAS.DWG
RECOMMENDED MAXIMUM INTERRAMP SLOPE ANGLE BY DESIGN SECTOR
CRIPPLE CREEK & VICTOR
SCALE 1"=1000'
FIGURE 1-1

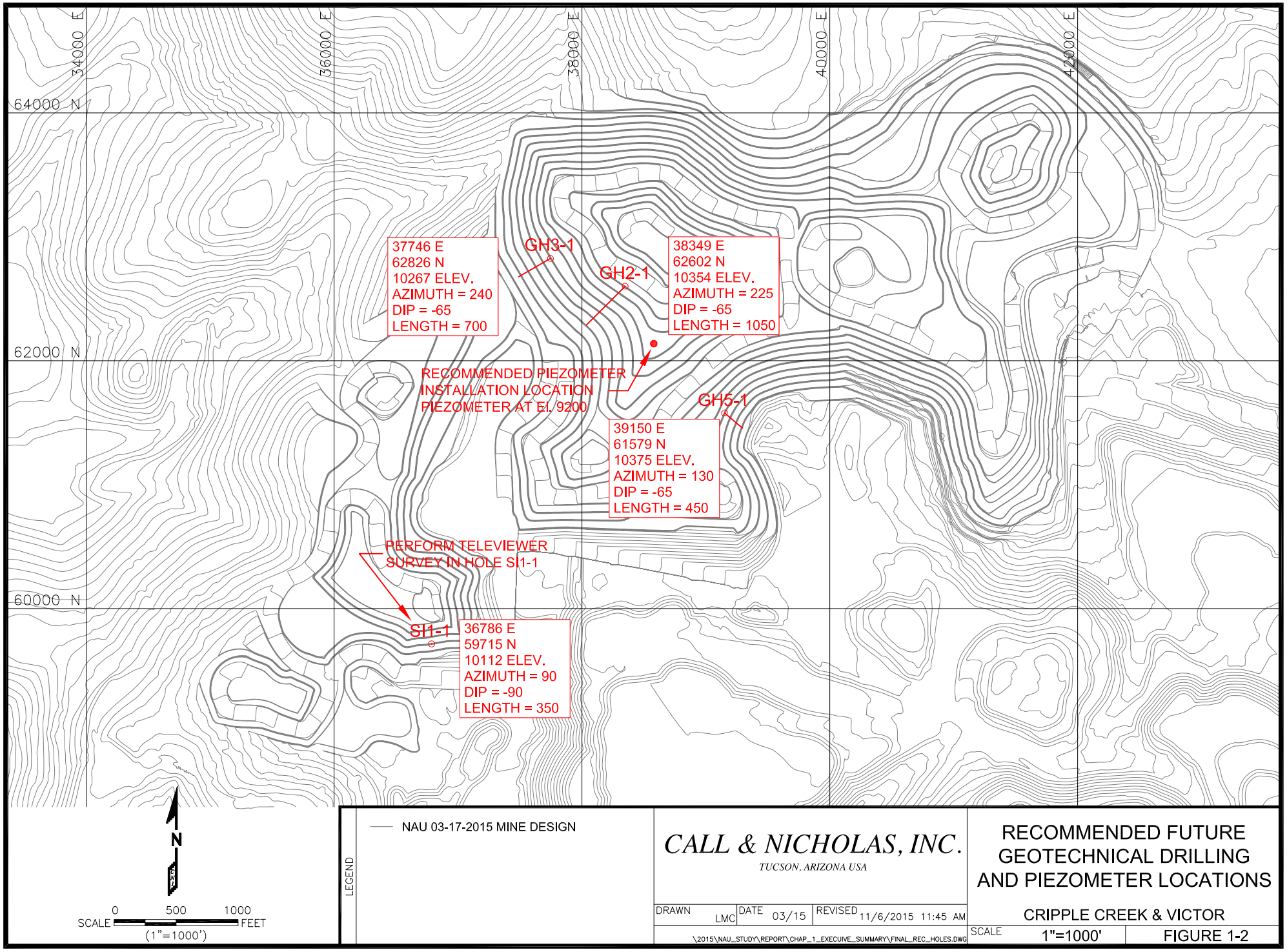

34000 E
36000 E
38000 E
40000 E
42000 E
64000 N
62000 N
60000 N
37746 E
62826 N
10267 ELEV.
AZIMUTH = 240
DIP = -65
LENGTH = 700
GH3-1
GH2-1
38349 E
62602 N
10354 ELEV.
AZIMUTH = 225
DIP = -65
LENGTH = 1050
RECOMMENDED PIEZOMETER
INSTALLATION LOCATION
PIEZOMETER AT EL. 9200
GH5-1
39150 E
61579 N
10375 ELEV.
AZIMUTH = 130
DIP = -65
LENGTH = 450
PERFORM TELEVIEWER
SURVEY IN HOLE SI1-1
SI1-1
36786 E
59715 N
10112 ELEV.
AZIMUTH = 90
DIP = -90
LENGTH = 350
N
0
500
1000
SCALE
FEET
(1"=1000')
LEGEND
NAU 03-17-2015 MINE DESIGN
CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA
DRAWN LMC
DATE 03/15
REVISED 11/6/2015 11:45 AM
\2015\NAU_STUDY\REPORT\CHAP_1_EXECUIVE_SUMMARY\FINAL_REC_HOLES.DWG
RECOMMENDED FUTURE
GEOTECHNICAL DRILLING
AND PIEZOMETER LOCATIONS
CRIPPLE CREEK & VICTOR
SCALE 1"=1000'
FIGURE 1-2

Figure 1-3. Recommended Workflow for Estimation of Q' Above Voids

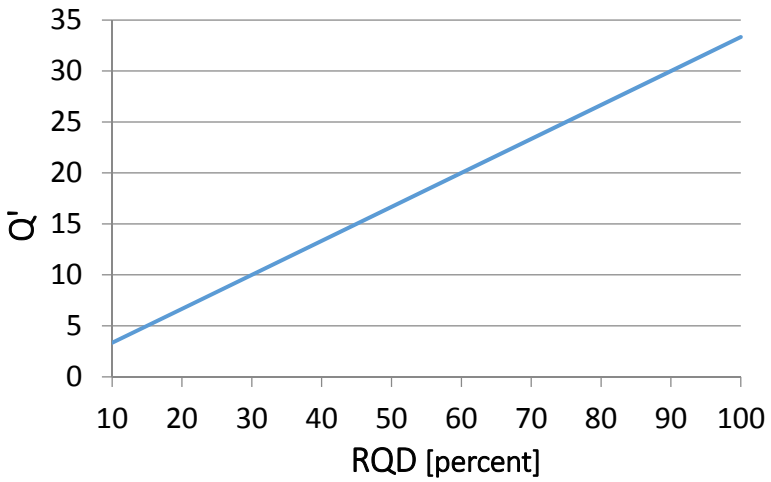
1. For *any* rock type if the Q' model is available above the void:

- Use the average Q' block model value in between the top of the void and the current topography surface.

2. If the Q' model is *not* available above the void:

If the rock type is Cripple Creek Breccia:

- Estimate the average RQD block model value in between the top of the void and the current topography surface. Use this RQD value with the calibrated conversion chart below to obtain the Q' value.

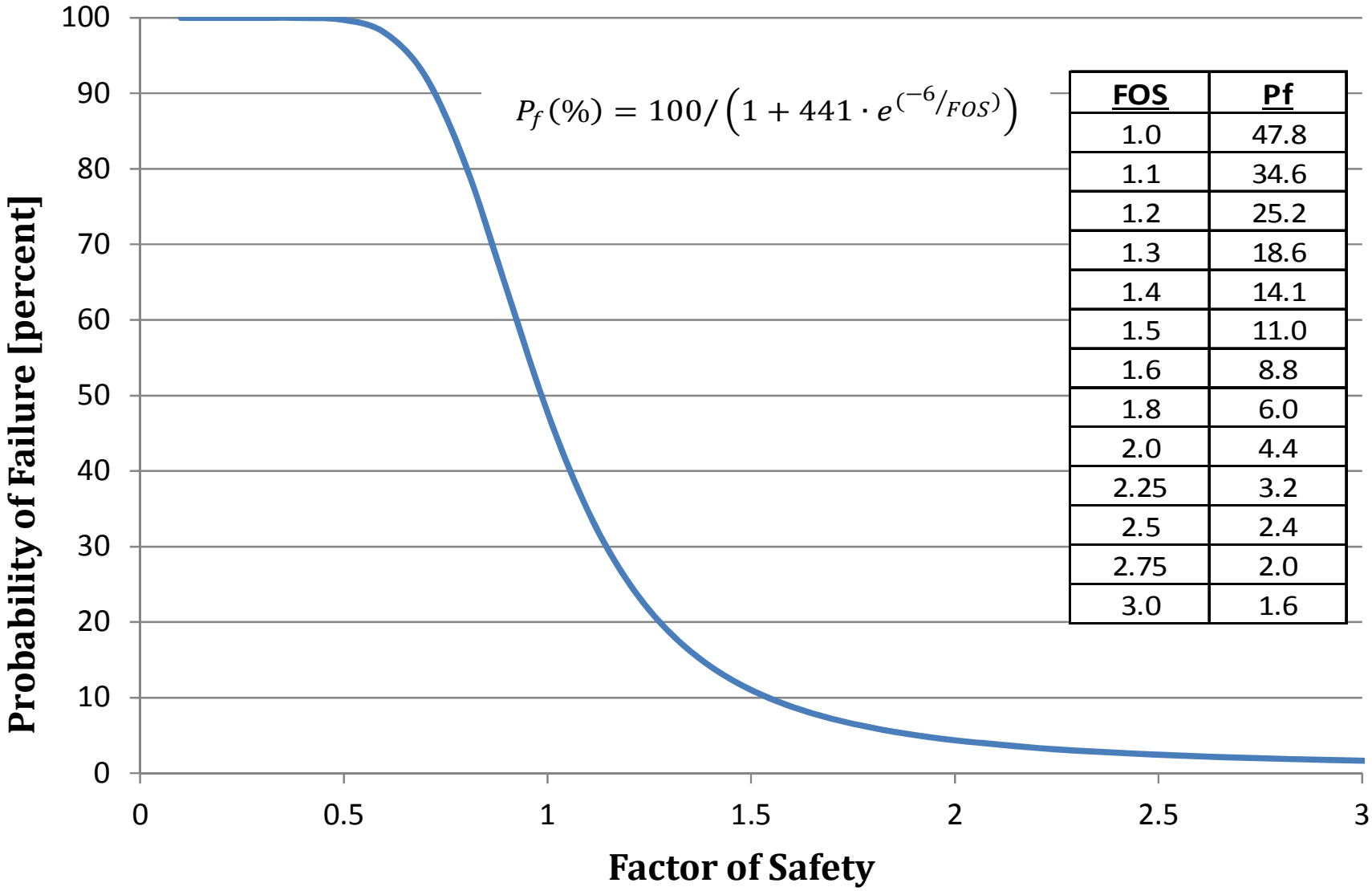


RQD	Q'
10	3.3
20	6.7
30	10.0
40	13.3
50	16.7
60	20.0
70	23.3
80	26.7
90	30.0
100	33.3

If the rock type is *not* Cripple Creek Breccia:

- Estimate the average RQD block model value in between the top of the void and the current topography surface. Use this RQD value with the applicable values from the table below to calculate the Q' value.

Rock Type	J_r	J_a	J_n	
			If RQD >= 40%	If RQD < 40%
Phonolite	2.0	1	9	12
Lamprophyre	1.5			
Schist (Pre-Cambrian)	1.5			



FOS	Pf
1.0	47.8
1.1	34.6
1.2	25.2
1.3	18.6
1.4	14.1
1.5	11.0
1.6	8.8
1.8	6.0
2.0	4.4
2.25	3.2
2.5	2.4
2.75	2.0
3.0	1.6

From: Carter, T.G. 2014. Guidelines for use of the Scaled Span Method for Surface Crown Pillar Stability Assessment. Accessed from https://www.academia.edu July 15, 2015.

Figure 1-4. Suggested Relation Between FOS and POF for Crown Pillar Stability Calculations

2.0 INTRODUCTION

This report presents the results of Call & Nicholas, Inc.'s (CNI) geotechnical evaluation of Cripple Creek & Victor Gold Mining Company's (CCV) proposed North Area Underground slope designs. For this design study, the geometric slope components (including bench configuration and interramp slope angles) were evaluated using geological and geotechnical data collected by both CCV and CNI personnel. Recommendations for bench design, interramp slope angles, and overall slope angles by design sector are based on the results of this investigation.

The 2015 NAU slope stability study was initiated in March 2015 following the acceptance of the proposal submitted by CNI to perform the work. Mr. Chris Hanks, the Chief Environmental Coordinator for CCV, provided the scope of work for this study.

2.1 Scope of Work

The investigation consisted of:

1. Determining geotechnically justifiable slope design angles for the NAU mining areas including the Wild Horse Extension (WHEX), Globe Hill, and Schist Island areas.
2. Testing strength samples collected from geotechnical core holes. Data were lacking in the Globe Hill pipe zone before this study.
3. Projecting the known geology on cross sections used in the overall slope analysis.
4. Generating a geotechnical block model based on the most recent drilling database.
5. Analyzing bench-scale stability based on cell mapping data collected in the WHEX mine.
6. Analyzing global slope stability for critical walls.
7. Providing recommendations for slope management over the life of the project.
8. Preparing a report to summarize the analyses and recommendations.

2.2 Previous Geotechnical Studies

All available geological and geotechnical data were compiled and reviewed from previous studies, and applicable data were incorporated into this study. Previous geotechnical studies performed by CNI include:

- (December 2005) *Geotechnical Review of the 2006 Pit Designs*. The purpose of this review was to evaluate the existing geotechnical criteria used by CCV to select slope angles. Mines evaluated included Main Cresson, Altman, Wildhorse, South Cresson, and Schist Island.

- (May 2009) *Cripple Creek and Victor Mine November 2008 Deep Cresson Pit Design Slope Recommendations*. This report investigated the stability of the November 2008 Deep Cresson Pit Design. The investigation included a site visit and laboratory testing program.
- (July 2010) *East Wall Deep Cresson Slope Stability Design Options*. This study reviewed the stability design criteria for the east wall of the Deep Cresson layback. The work was performed to determine if there was any upside potential for steepening the interramp angle on the east wall.
- (April 2011) *Cripple Creek and Victor Mine Wild Horse Extension Pit Design Slope Recommendations*. This was the first geotechnical evaluation of the July 2010 Wild Horse Extension (WHEX) mine design.
- (October 2011) *Geotechnical Slope Design Recommendations for the MLE2 Mining Areas*. This report presented the geotechnical slope evaluation of the mining areas associated with the Mine Life Extension 2 Project (MLE2).
- (June 2012) *Analysis of West Cresson Slope Stability when Mining Exposes Stopes at the Toe of the Designed Slopes.* This study investigated potential slope stability issues related to stopes that will be exposed in the toe of the east wall of the Cresson Mine and the risk they may pose to overall wall stability.
- (October 2012) *Evaluation of Dike Plane Shear Sliding Potential – East Cresson 9525 Ramp.* This report summarized the analysis of potential plane shear sliding on a phonolite dike which was striking parallel to the pit.
- (October 2014) *Cripple Creek July 2014 Cell Mapping Summary.* This memo summarized the results of a geotechnical surface mapping campaign in both the WHEX and Cresson mines performed during July 2014.

3.0 ENGINEERING GEOLOGY

When designing optimum slope angles for open pits, there are many important geological factors to consider, including:

1. The lithology, including alteration
2. The rock fabric (joints)
3. The major structures including faults and lithologic contacts
4. The hydrogeology

This chapter contains brief descriptions of the important geological factors as they relate to the geotechnical analysis of the pit designs.

3.1 Geology

The Cripple Creek gold mine is located within a Tertiary alkaline diatreme complex that has been dated from 34 to 32 Ma (White et al.). The bulk of the volcanic complex is composed of the Cripple Creek breccia unit, which is a heterolithic diatreme breccia with volcanoclastic sediments and bedded tuffs. The breccia has been intruded by many phonolite and ultramafic lamprophyre dikes, pipes, and sills. The dikes are typically vertical or sub-vertical. Country rocks surrounding the volcanic diatreme are Precambrian granites, gneiss, and schist. The diatreme rocks in the NAU study area are generally blocky with moderate permeability and sub-vertical jointing that strikes NE-SW and NW-SE. The Precambrian schist and gneiss can contain foliation that typically dips to the north or northwest at angles between 30 and 70 degrees.

3.1.1 Geotechnical Rock Groups (GTRCK)

When performing an engineering study, the most important physical characteristics of a rock type are the shear strength properties of the rock. The strength properties are measured in a rock mechanics laboratory on samples taken directly from the mine site. Since only a limited number of strength tests can be performed for slope stability studies, lithologic units are grouped into engineering rock units. Minor composition and textural differences in rock types often have little influence on rock strength. For the NAU study, the geotechnical engineering rock type groups (GTRCK) are described below. Figure 3-1 shows the projected geotechnical rock units that will be exposed by plans.

1. Cripple Creek breccia (TBX)

   This rock is a light brown to gray, moderately-hard to hard, poorly sorted breccia with subrounded to subangular clasts. The clasts are mostly lapilli-size (approximately 0.1 to 1 inch) phonolite fragments in a matrix of phonolite composition.

2. Porphyritic phonolite (TPH)

   In a fresh condition, this rock type consists of a moderately hard to hard medium-grained light gray porphyritic rock. It is light brown where weathered.

3. Lamprophyre (TLU)

   This rock unit consists of a moderately hard, dark green to black medium-grained porphyry. It forms dikes and a cylindrical pipe in the western walls near the bottom of the Main Cresson Mine. This geotechnical unit is not expected to occur in the slopes of the NAU mine plans.

4. Precambrian (XBS, XBG, XGD, YCC, YPP)

   The Precambrian rocks are the host rocks into which the diatreme intruded. This rock unit consists of Precambrian biotite schist, gneiss, granite, and monzonite. The schist and gneiss rocks can contain weak and persistent foliation planes. The granites can be hard and massive. The schistose rocks have a very weak anisotropic strength in the direction of the schistosity. For this reason, it would be beneficial to identify the schist member of the Precambrian as its own geotechnical rock type. It would be beneficial to break out the different Precambrian rock types in the lithology wireframe model.

5. Globe Hill Pipe

   The Globe Hill pipe is a highly fractured and altered zone located in the central and southern portions of the proposed Globe Hill mine. The pipe is considered as a separate geotechnical rock type because the shear strength of this material is expected to be significantly lower than that of the surrounding less fractured rock mass, even though the pipe is composed primarily of Cripple Creek breccia and Phonolite. The pipe is highly fractured with a RQD value typically less than 5 percent. Photos of core recovered from the Globe Hill pipe zone show the poor quality rock mass (Figure 3-2). Any blocky intervals within the pipe are typically cemented by the mineral anhydrite, which is highly expansive when exposed to water. It is possible that historic rehydration of anhydrite in this zone caused swelling pressures which shattered the surrounding rock mass.

6. Unconsolidated Colluvium / Weathered Zone

   In some areas of the NAU the bedrock units are overlain by a layer of unconsolidated colluvium. The colluvium is characterized as a clayey medium to coarse-grained sand with gravel. The colluvium is slightly cohesive. It ranges from zero to two-hundred feet in thickness depending on location. This geotechnical unit also includes the near-surface weathered zone of geotechnical rock types 1 through 5.

7. Mine Backfill

   The Globe Hill pit has been previously mined to a depth of approximately 320 feet and backfilled with overburden material from other mines within the CCV complex. The backfill consists of clean volcanic particles with low clay content. Most of the backfill will be removed completely during excavation of the new pit, except for a 200-foot-high portion of backfill that will be exposed in the final wall of the southeastern Globe Hill mine.

Geologic cross sections constructed to perform overall slope stability analyses are presented in Chapter 6.

3.2 Structural Geology

In pit slope design, structures are separated into three categories: major structures, intermediate structures, and rock fabric. Major structures are defined as those structures that either divide the pit into structural domains (areas in which rock fracture orientations and characteristics are similar) or intersect the entire length or height of the pit slope. Intermediate structures are considered to be those structures that can intersect multiple bench levels but not necessarily the entire pit. Rock fabric consists of small-scale structures such as joints and foliation.

3.2.1 Rock Fabric Data

In the process of pit slope design, major continuous structures are usually indentified and their effect on pit slopes is assessed individually. Minor discontinuous structures, such as joints, foliation, and bedding joints are collectively termed *rock fabric*. However, bedding planes and foliation can be classified as intermediate to large-scale structures in some circumstances. Bedding and foliation in adverse orientations provide anisotropies in the rock mass that can form

large-scale weakness paths resulting in instability. These short structures usually affect bench-scale stability. Because of the highly variable nature of the rock fabric, statistical methods are used to characterize the orientation, length, and spacing of these shorter structures.

Cell Mapping

The distribution of the orientation, length, and spacing of the minor structures must be obtained for use in bench-scale and global stability analyses. Cell mapping provides an efficient method to collect this information in a statistical fashion. In cell mapping, the benches are first divided into equal-dimensional "cells" (50-feet wide by 35-feet high for single benches and 50-feet wide by 70-feet high for double benches). When mapping a cell, the minimum bench face angle and the strike of the cell are first measured. Small-scale fractures are grouped into sets of structures that have similar orientation. Characteristics of the sets are then recorded. These characteristics include average orientation (strike and dip), maximum length, counting distance, number of fractures (for spacing calculations), rock type, and infill type. Structure count, count length, count orientation, cell orientation, and structure orientation are used to calculate the true mean spacing for each mapped structure set. The size of the cell window, structure count, number of structures at the maximum length, lower length truncation limit, and observed maximum length are used to calculate the true mean length for each structure set. After completing these two calculations for individual structure measurements within each cell, the structure data are ready for analysis.

Cell mapping data in the NAU area have been collected in 2010, 2014, and 2015 on exposed benches in the WHEX mine by both CCV and CNI engineering staff. The cell locations are plotted on the map presented in Figure 3-3. In total 212 cells were mapped on the 9990, 9935, 10005, 10040, 10075, 10120, 10155, 10250, 10285, 10355, and 10390 benches.

The measured rock fabric data from the WHEX mine is plotted on lower hemisphere Schmidt nets in Figures 3-4 through 3-6 for the Cripple Creek breccia, phonolite, and Precambrian rock types. The geologic structure sets are labeled on the figures along with a table containing the statistics of each set. Both the breccia and phonolite have sub-vertical joint sets that strike NE-SW and NW-SE, and a flatter set that dips to the northeast at approximately 50 degrees. The Precambrian rock is dominated by a long foliation set that dips to the N-NW at 40 degrees, in addition to a suite of cross-joint and release joint sets.

3.2.2 Televiewer Structure Data

Acoustic televiewer surveys can be used to obtain rock fabric information from boreholes where no surface exposure exists. Televiewer survey hole CPC14-1 in the Schist Island mine was evaluated to see if the foliation orientation in the schist could be determined. The structural data measured from closest schist intercept to the planned pit design is plotted on a stereonet in Figure 3-7. If this plot is compared to the Precambrian cell mapping data collected in the WHEX (Figure 3-6), it appears that the foliation is in the same orientation dipping to the north-northwest. Therefore, the cell mapping data collected in the Precambrian in the WHEX will also utilized for analysis in the Precambrian rock in the Schist Island area.

3.2.3 Major/Intermediate Structure Data

Major and intermediate size structures that could affect stability of the NAU area include contacts between rock types, faults, shear zones, dikes, and anisotropies caused by bedding and foliation. Major structure mapping was conducted in the WHEX mine by CCV and CNI geologists. These data set are used to run multi-bench interramp stability analysis. The major structures are plotted on a lower hemisphere Schmidt net in Figure 3-8. As shown in the figure, the steep NE-SW trending conjugate shear structures are also well represented in the major structure mapping, with very few shallow dipping structures that could act as plane shear sliding mechanisms.

3.3 Block Model

CCV mine personnel provided geologic, drill-hole, and mine design data in the form of digital MineSight files that were used to develop the block models. A total of 413 drill holes with RQD data were included in the drill-hole files out of a total database of 425 drill holes. CNI generated basic statistics on the drill holes but made no attempt to verify or otherwise reconcile the drill-hole database. Three-dimensional lithology was provided to CNI in the form of MineSight 3D wireframes (CC&V_Geol_wireframes.zip) that were coded to a block model.

3.3.1 RQD Block Model

Rock quality designation (RQD) is defined as a modified percent core recovery from drilling which only includes sound pieces of core longer than 4 inches in length. RQD can be used as a method of assessing rock quality as it relates to the degree of fracturing within the in

situ rock-mass. The IDW (inverse distance weighted) estimation technique was used to estimate the RQD into the block model. It has been found that an IDW estimate and smaller composite size tends to retain the distribution of the composites for the low and high range of the distribution. Kriging, although better visually, tends to smooth the distribution to the mid-range of the RQD distribution. For geotechnical studies, it is critical to identify and retain any low rock quality areas in the block model estimate. Table 3-1 shows basic RQD statistics on drill-hole data for the primary rock types. Table 3-2 shows the rock types in the geologic block model and the geotechnical rock groups that were used during the final estimation process.

The RQD model exposed on the NAU designs are presented in Figure 3-9. RQD is generally predicted to be fair to good in the NAU mine areas, except for zones of poor RQD in the north wall of the WHEX mine and central and southern portions of the Globe Hill mine within the Globe Hill pipe.

An in-depth discussion of the methodology used to create the RQD block model can be found in the May 2015 CNI report titled, *2015 Geotechnical Block Model*, and attached as Appendix C of this report.

3.3.2 Q' Block Model

One-hundred and ninety drill holes contained the necessary data for calculation of the rock mass parameter Q'. The data needed to calculate Q' are RQD, Jr (joint roughness), Jn (joint set number), and Ja (joint alteration number). While the parameters Jr, Jn, and Ja were not directly collected in the drill logs, information of sufficient detail regarding joint roughness and alteration was collected to allow for conversion to the Q' parameters. The conversion scale utilized for the estimation of Q' is shown in Table 3-3 and Q' was calculated using the following formula:

$$Q' = \frac{RQD}{Jn} \times \frac{Jr}{Ja}$$

The Q' model exposed on the NAU designs are presented in Figure 3-10.

3.4 Hydrogeology

When a slope is saturated with water, the pressure from the water reduces the normal stress and therefore the frictional resistance, resulting in a lower total shear resisting strength.

Water also increases the unit weight of the rock mass. The combination of these two effects reduces the factor of safety of a slope and can result in slope instability.

The Cripple Creek mining district is underlain by an extensive networking of historic underground workings from prior mining activity, including a series of tunnels designed specifically for water drainage. The drainage tunnels include the Moffat (approx. 9,000 feet elevation), the Roosevelt (approx. 8,000 feet elevation), and the 6.3-mile-long Carlton Drainage Tunnel (constructed between 1939 and 1941) driven from an elevation of 7000 feet. These drainage tunnels are assumed to effectively gravity drain the underground workings below the CCV pits to an elevation of 7,000 feet. The Carlton Drainage Tunnel reports to Four Mile Creek seven miles from the CCV mine. The permeability in the diatreme is typically greatest in the vertical direction due to the pair of sub-vertical joint sets that are usually present. Depressurized conditions are therefore typically assumed for slope stability analysis within the diatreme.

It is still possible for zones of perched water to exist above the drained zone which may cause pore pressures in some slopes. It is anticipated that the Precambrian rocks will have the highest potential for perching water on the deformed foliation planes in the schist and gneiss. CNI has not been provided with any piezometer data, and as such a sensitivity to water pressures will be performed for the global slope stability analysis to determine the effect perched water may have on slope stability (Chapter 6).

Table 3-1. Drill Hole Database RQD Statistics

CCV Rock Code	Rock Type Description	Total Drill Intervals	Total Length [ft]	Minimum RQD Value	Mean [percent]	Maximum RQD Value	Standard Deviation	Coeff. Of Variation
12	Syenite	587	5172	0	69	100	27	0.40
22	Syenite	34	289	0	65	100	26	0.40
23	Syenite	309	3018	0	59	100	31	0.53
31	Porphyritic phonolite with K-spar	2447	20391	0	65	100	26	0.39
33	Porphyritic phonolite with K-spar	240	1918	0	56	100	26	0.47
35	Porphyritic phonolite with K-spar	8	98	0	32	73	30	0.91
40	Hydrothermal Breccia	676	5559	0	61	100	33	0.53
41	Hydrothermal Breccia	60	342	0	32	90	31	0.99
51	CC Breccia	5042	46617	0	64	100	28	0.44
63	Pre-Cambrian granodiorite	20	194	72	84	95	7	0.09
84	Lamprophyre-matrix breccia	46	409	0	65	100	31	0.48
85	Lamprophyre-matrix breccia	23	973	16	66	96	16	0.24

Total	9,492	84,979

Table 3-2. Cripple Creek Geology Wireframes and Geotechnical Model Rock Groups (GTRCK)

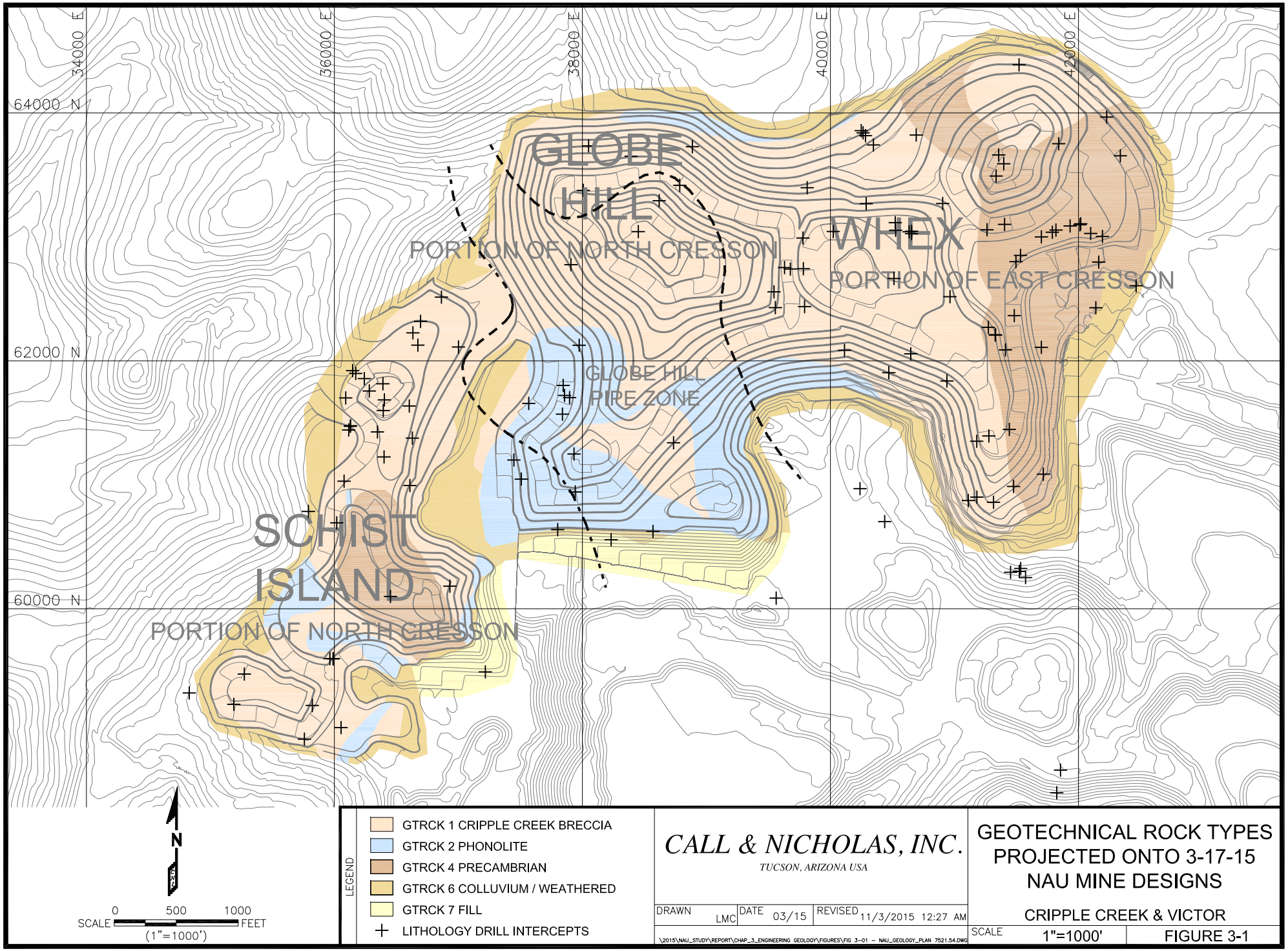
CCV Wireframe Name	CCV Rock Code	Rock Type Description	GTRCK Name	GTRCK Number	GTRCK Percentage
TTD	7	Trachydolerate	Trachydolorite	--	0.02
TTD ISABELLA flt					
TSY 1	12	Syenite	Phonolite	2	6.91
TPHA 1	22	Undifferentiated aphanitic phonolite			
TPHA 2	23				
TPHA 3 FAULT					
TPHK 1	31	Porphyritic phonolite with K-spar			
TPHK 2	32				
TPHK 3	33				
TPHK 4	34				
TPHK 5	35				
THBX	40	Hydrothermal Breccia	Breccia	1	36.57
THBX Collapse	41				
TBX	51	Cripple Creek Breccia			
PC	63	Pre-Cambrian	PC	4	56.41
TLBX 1	84	Lamprophyre-matrix breccia (Dikes)	Lamprophyre	3	0.10
TLBX 2	85	Lamprophyre-matrix breccia (Pipe)			
TLBX 3 FAULT		Lamprophyre-matrix breccia (Fault)			

Table 3-3. Drill Hole Coding Logic for Q' Model Parameters

CCV Logged Joint Roughness	Jr
1	1
2	
3	2
4	3
5	3.5
6	
7	
8	4
9	
10	

CCV Logged Joint Alteration	Ja
Clay	4
Fresh	1
Healed	1
Open	1
Oxide	2
Sandy	3
Slick	4
Weathered	2

RQD (percent)	Jn
0-20	15
20-60	12
60-100	9


34000 E
36000 E
38000 E
40000 E
42000 E
64000 N
62000 N
60000 N
GLOBE HILL
PORTION OF NORTH CRESSON
WHEX
PORTION OF EAST CRESSON
GLOBE HILL PIPE ZONE
SCHIST ISLAND
PORTION OF NORTH CRESSON
N
TRUE
0
500
1000
SCALE
FEET
(1"=1000')
LEGEND
GTRCK 1 CRIPPLE CREEK BRECCIA
GTRCK 2 PHONOLITE
GTRCK 4 PRECAMBRIAN
GTRCK 6 COLLUVIUM / WEATHERED
GTRCK 7 FILL
LITHOLOGY DRILL INTERCEPTS
CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA
DRAWN LMC
DATE 03/15
REVISED 11/3/2015 12:27 AM
\2015\NAU_STUDY\REPORT\CHAP_3_ENGINEERING GEOLOGY\FIGURES\FIG 3-01 - NAU_GEOLOGY_PLAN 7521.54.DWG
GEOTECHNICAL ROCK TYPES
PROJECTED ONTO 3-17-15
NAU MINE DESIGNS
CRIPPLE CREEK & VICTOR
SCALE 1"=1000'
FIGURE 3-1

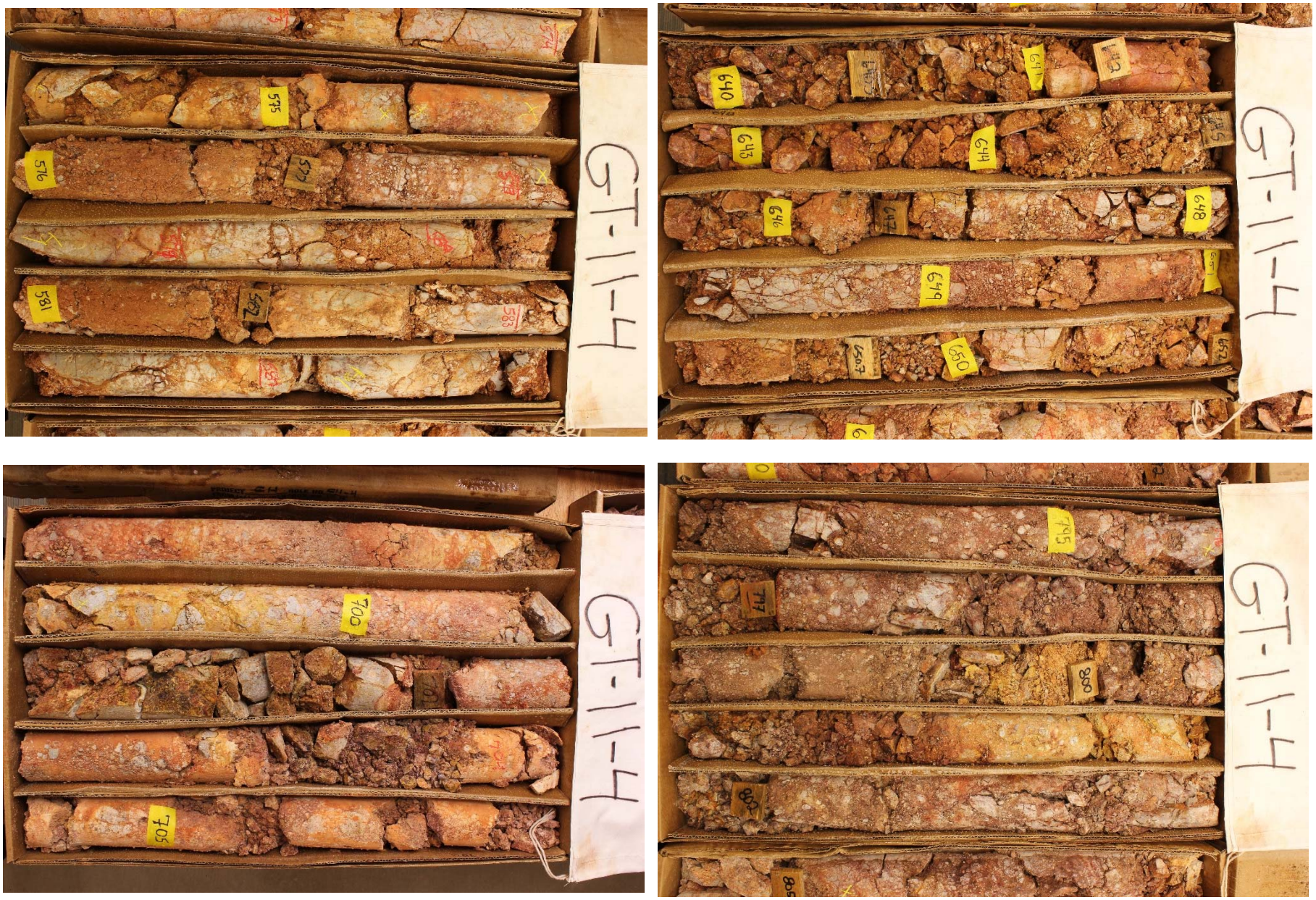
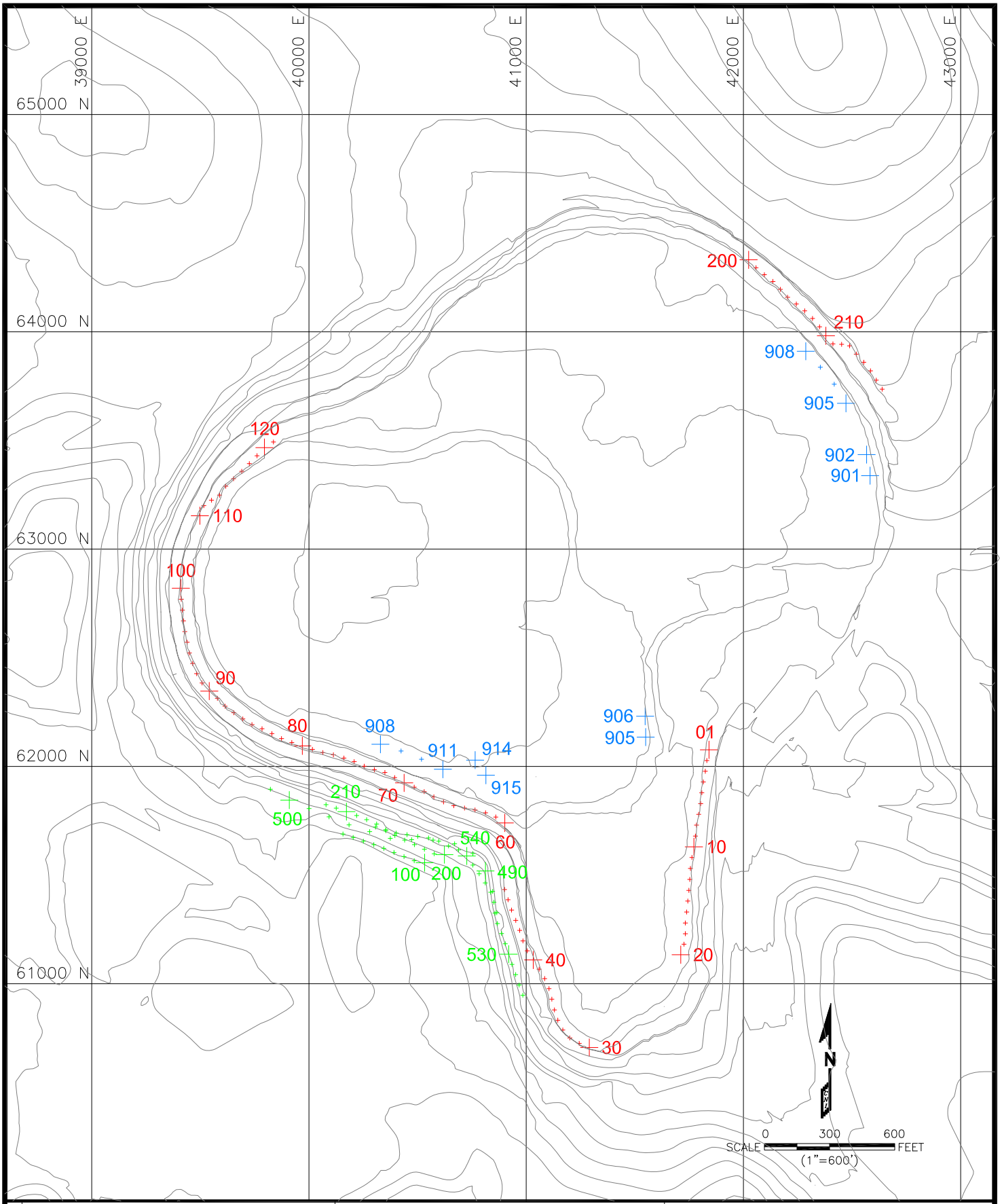


Figure 3-2. Photos of core from hole GT11-04 that are typical of the Globe Hill pipe zone.



LEGEND

902 + 2015 CELL MAPPING LOCATIONS

01 + 2014 CELL MAPPING LOCATIONS

100 + 2011 CELL MAPPING LOCATIONS

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DRAWN	DATE	REVISED
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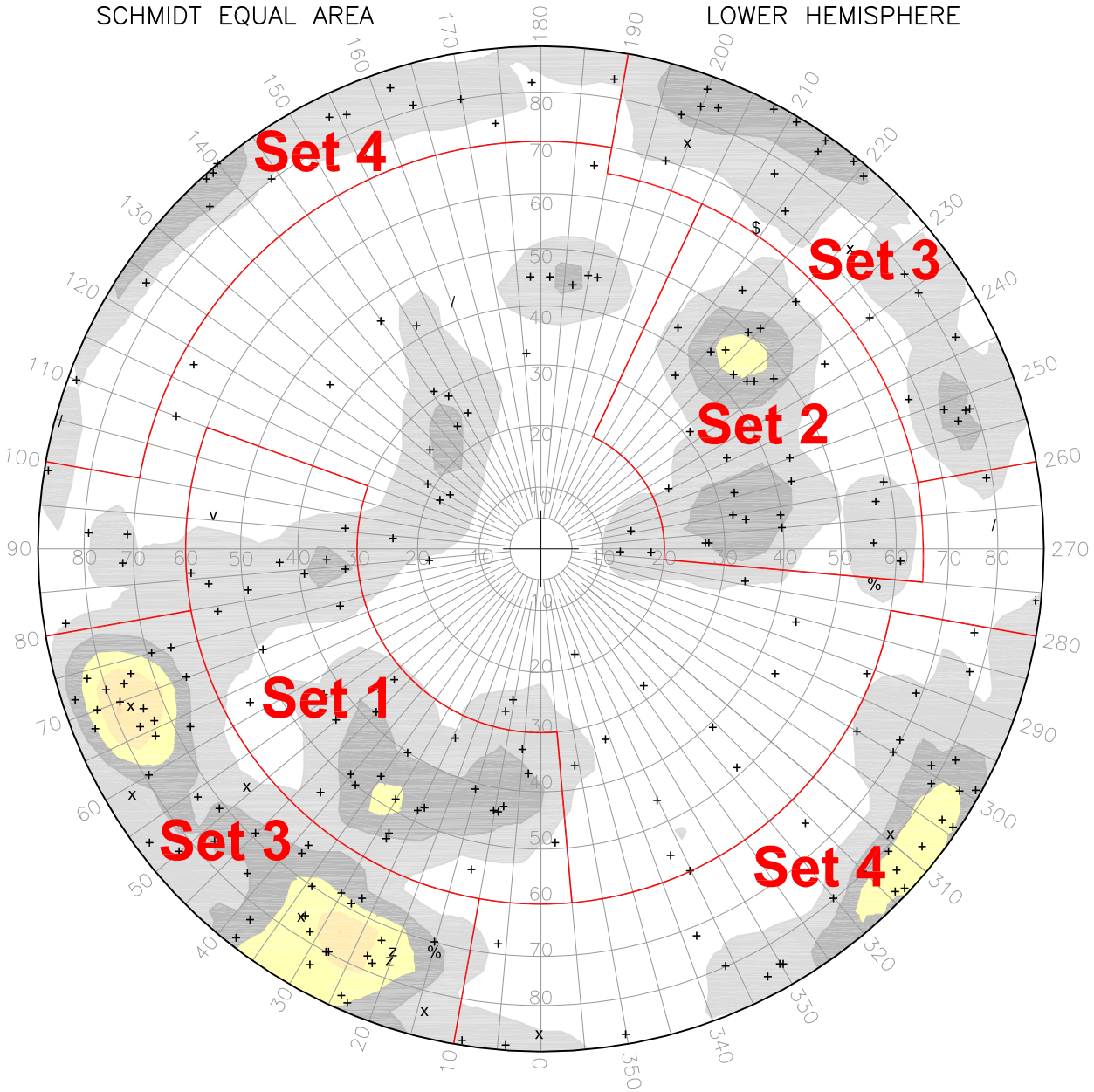
\2015\NAU_STUDY\REPORT\CHAP_3_ENGINEERING GEOLOGY\FIGURES\FIG 3-03 - WHEX_CELL_LOC.DWG

WHEX CELL MAPPING LOCATIONS ON JUNE 2015 TOPO

CRIPPLE CREEK & VICTOR

SCALE 1"=600'

FIGURE 3-3



CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 241

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
Set1	46.59	44.78	4.10	22.43	59.3%
Set2	243.31	43.52	3.87	15.14	50.0%
Set3	44.86	84.07	2.60	12.76	100.0%
Set4	321.76	85.50	3.91	12.94	77.8%

\2015\NAU_STUDY\REPORT\ENGINEERING GEOLOGY\FIGURES\FIG 3-04 - TBX.DWG

10/4/2015 4:13 PM

File: TBX.met

Figure 3-4.
WHEX Mine Cell Mapping Data
Cripple Creek Breccia

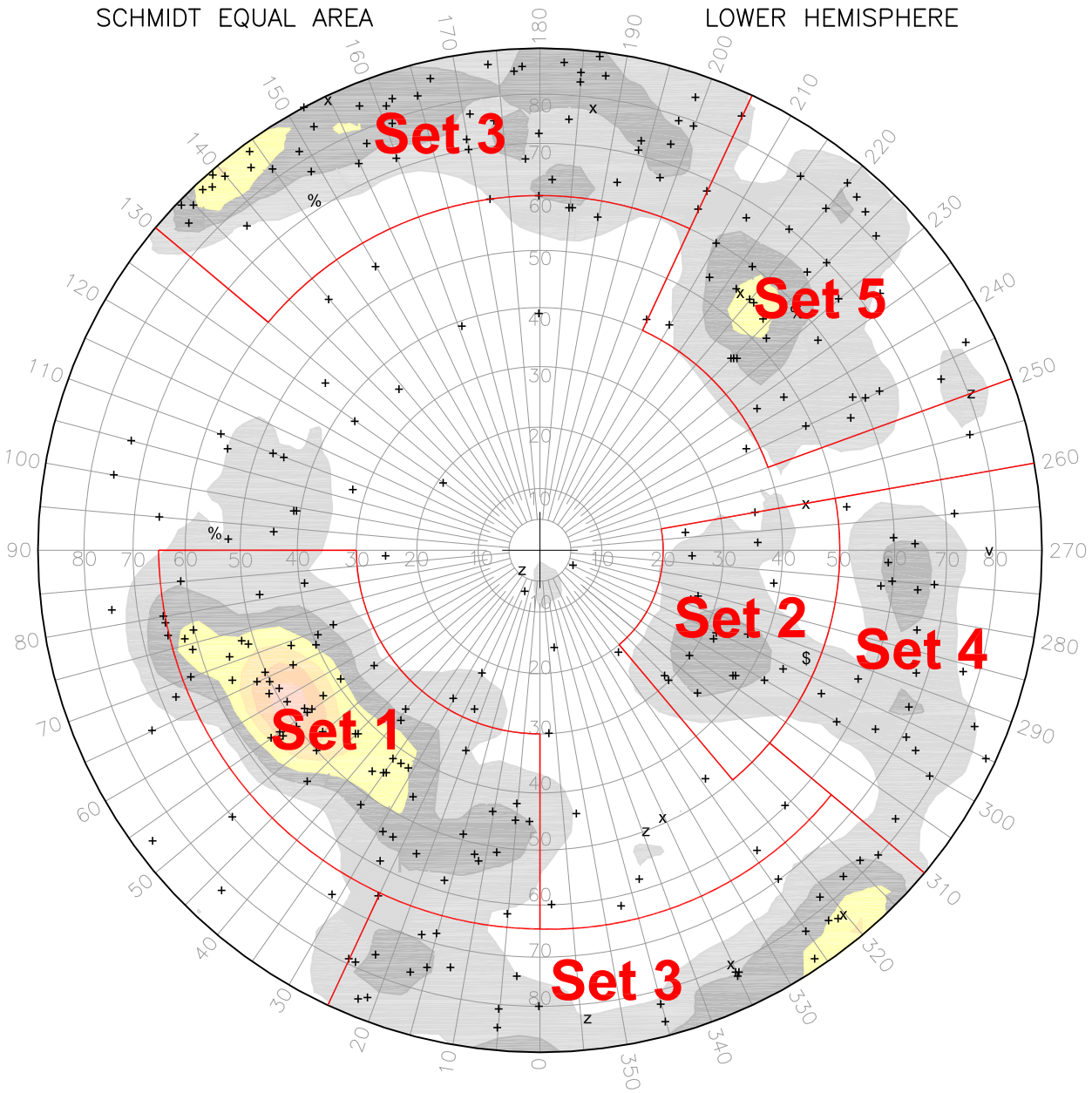


Figure 3–5.
WHEX Mine Cell Mapping Data
Phonolite

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TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 290

FISHER CONCENTRATION:

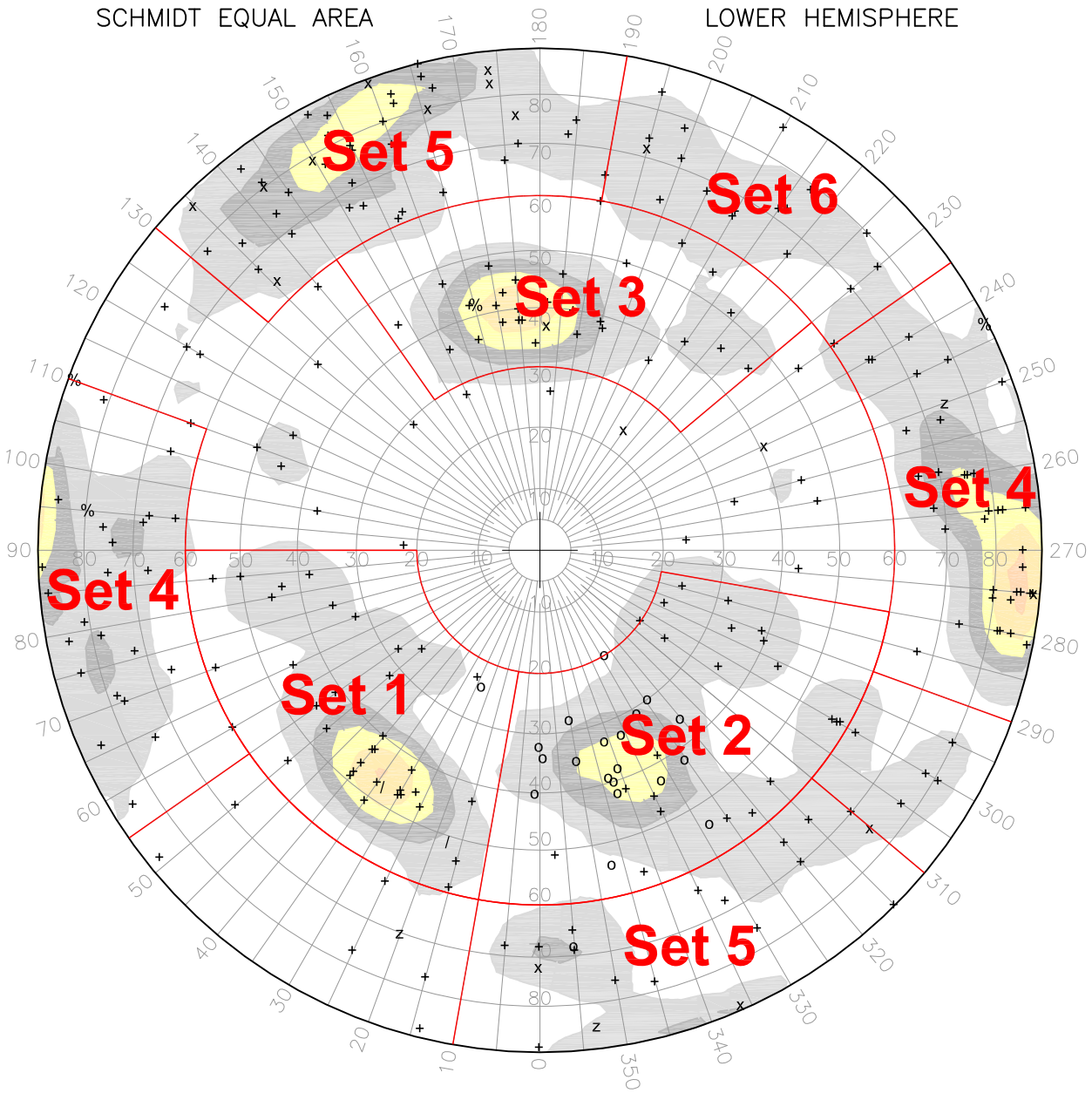
0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
Set1	47.97	49.56	5.63	15.19	93.3%
Set2	290.00	34.75	7.49	23.51	33.3%
Set3	167.21	86.50	5.23	9.10	100.0%
Set4	284.80	67.64	5.20	8.79	41.7%
Set5	212.27	65.56	5.18	13.18	61.7%

\2015\NAU_STUDY\REPORT\ENGINEERING GEOLOGY\FIGURES\FIG 3-05 - TPH.DWG

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TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 286

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

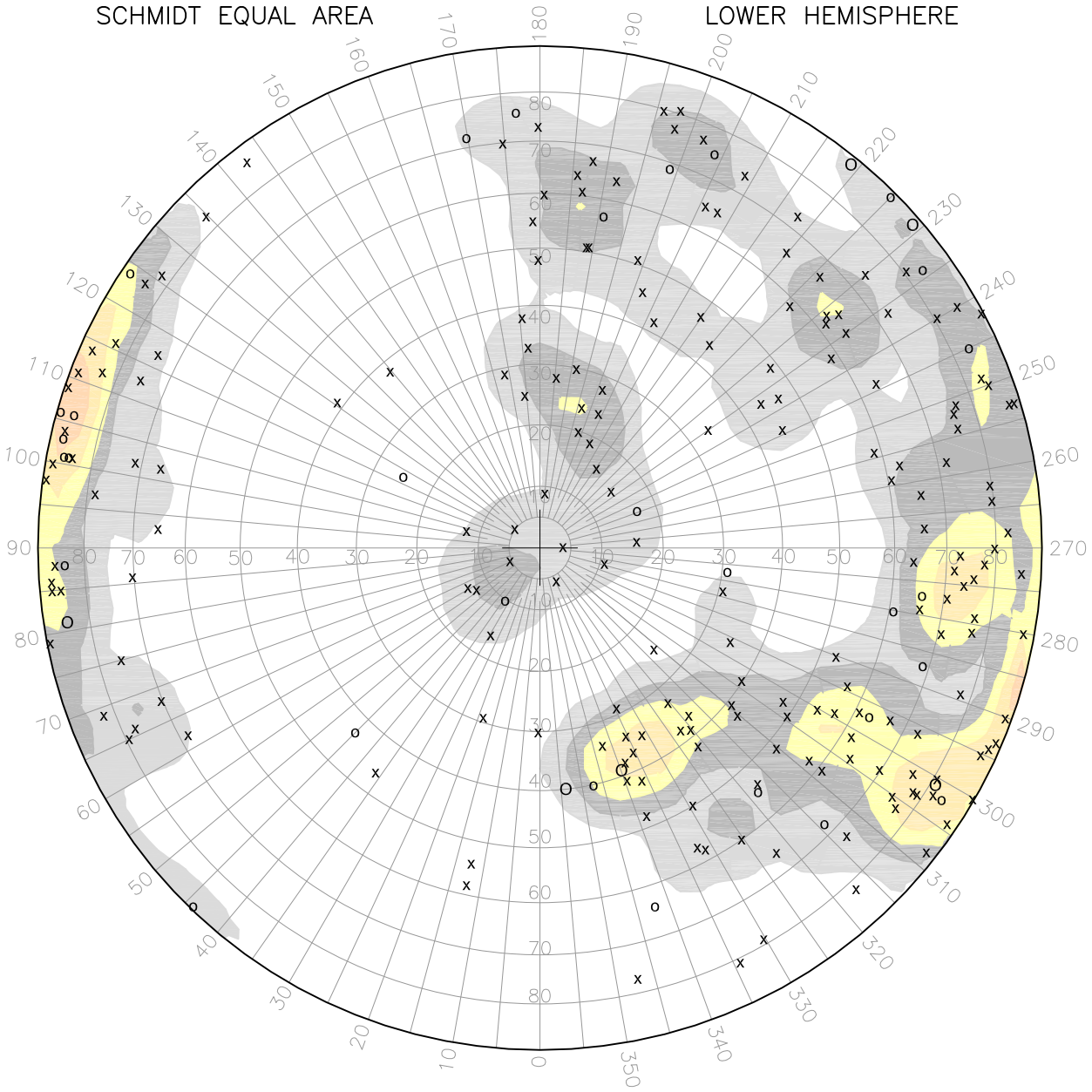
SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
Set1	45.59	43.65	5.48	25.88	54.5%
Set2	324.44	40.02	2.75	26.84	69.1%
Set3	186.14	42.31	3.31	13.09	43.6%
Set4	264.51	89.08	3.15	17.33	100.0%
Set5	157.23	86.77	2.87	14.53	72.7%
Set6	182.35	80.10	2.69	10.41	34.5%

\2015\NAU_STUDY\REPORT\ENGINEERING GEOLOGY\FIGURES\FIG 3-06 - XGD.DWG

8/12/2015 3:54 PM

File: XGD.met

Figure 3-6.
WHEX Mine Cell Mapping Data
Pre-Cambrian



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PLOT LEGEND

NUMBER OF POINTS: 233

FISHER CONCENTRATION:

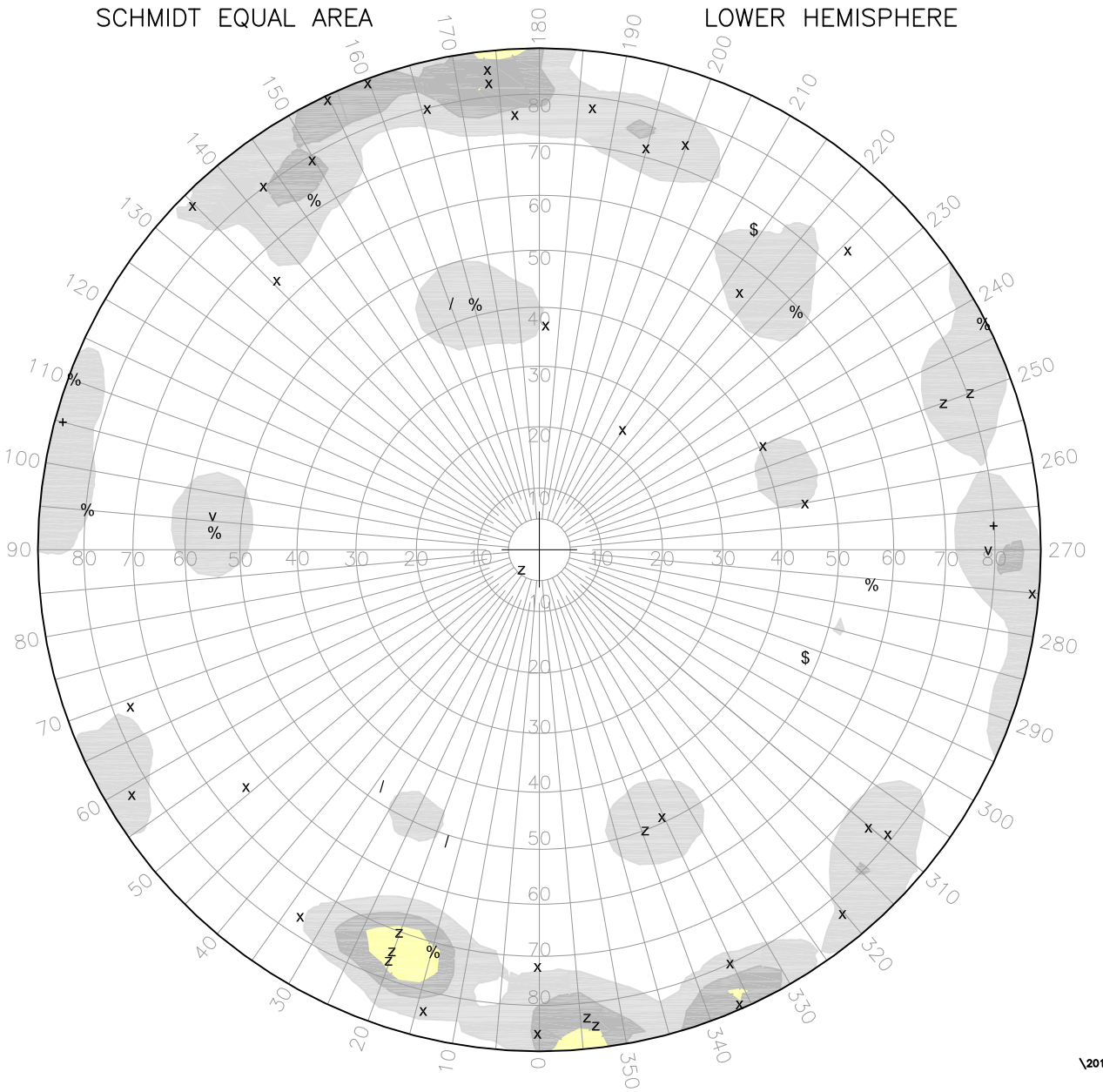
- 0.0% ~ 1.0%
- 1.0% ~ 2.0%
- 2.0% ~ 3.0%
- 3.0% ~ 4.0%
- 5.0% ~ 6.0%
- 6.0% ~ 7.0%

\2015\NAU_STUDY\REPORT\CHAP_3_ENGINEERING GEOLOGY\FIGURES\FIG 3-07 - CPC14-1_300_450.DWG

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File:

Figure 3–7.
Hole CPC14–1 Televiewer Structure Data, Schist Island
Depth 300 to 450 feet, Precambrian Schist



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TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = DIKE SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 60

FISHER CONCENTRATION:

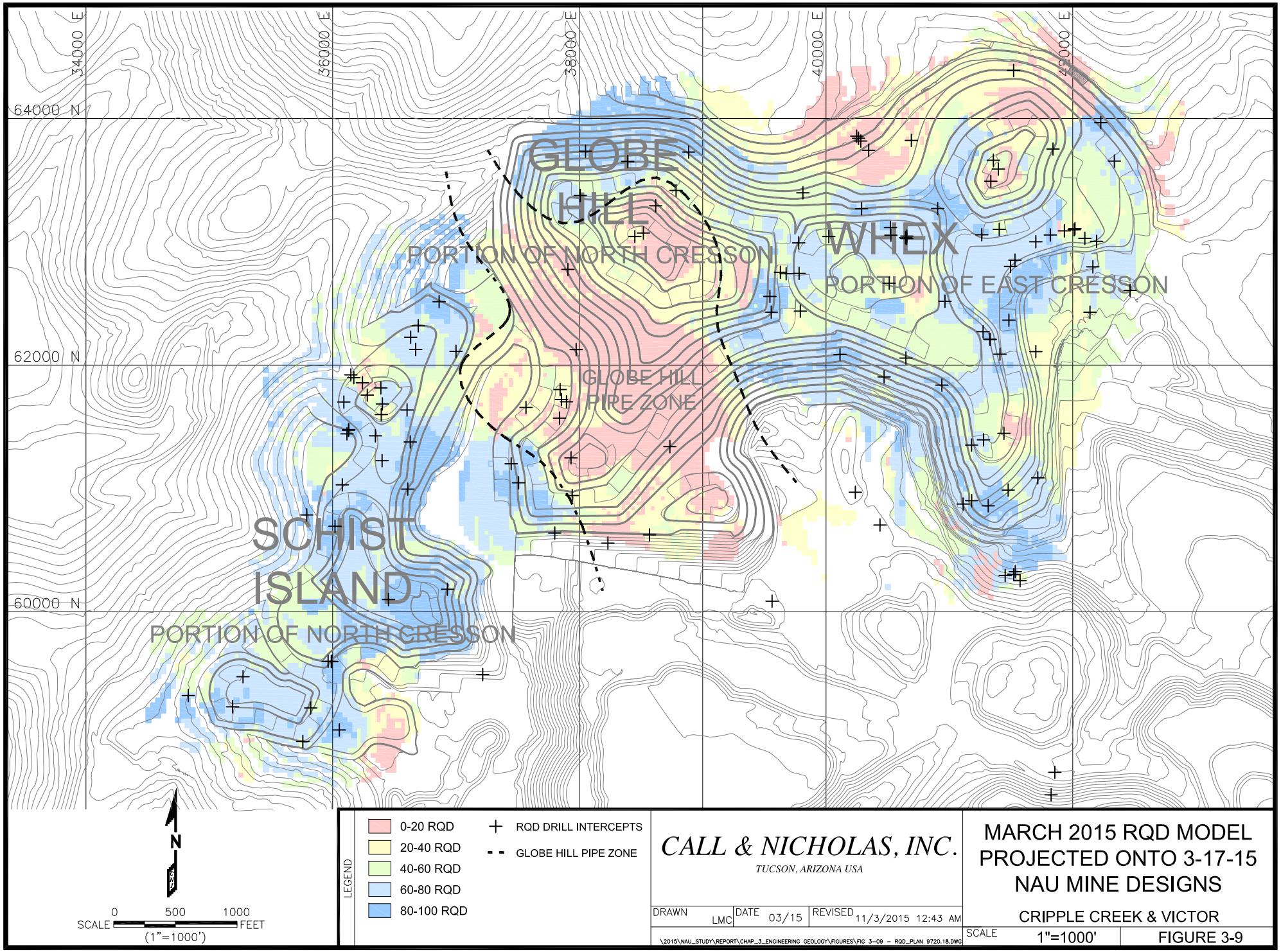
0.0% ~ 2.0%
2.0% ~ 4.0%
4.0% ~ 6.0%
6.0% ~ 8.0%

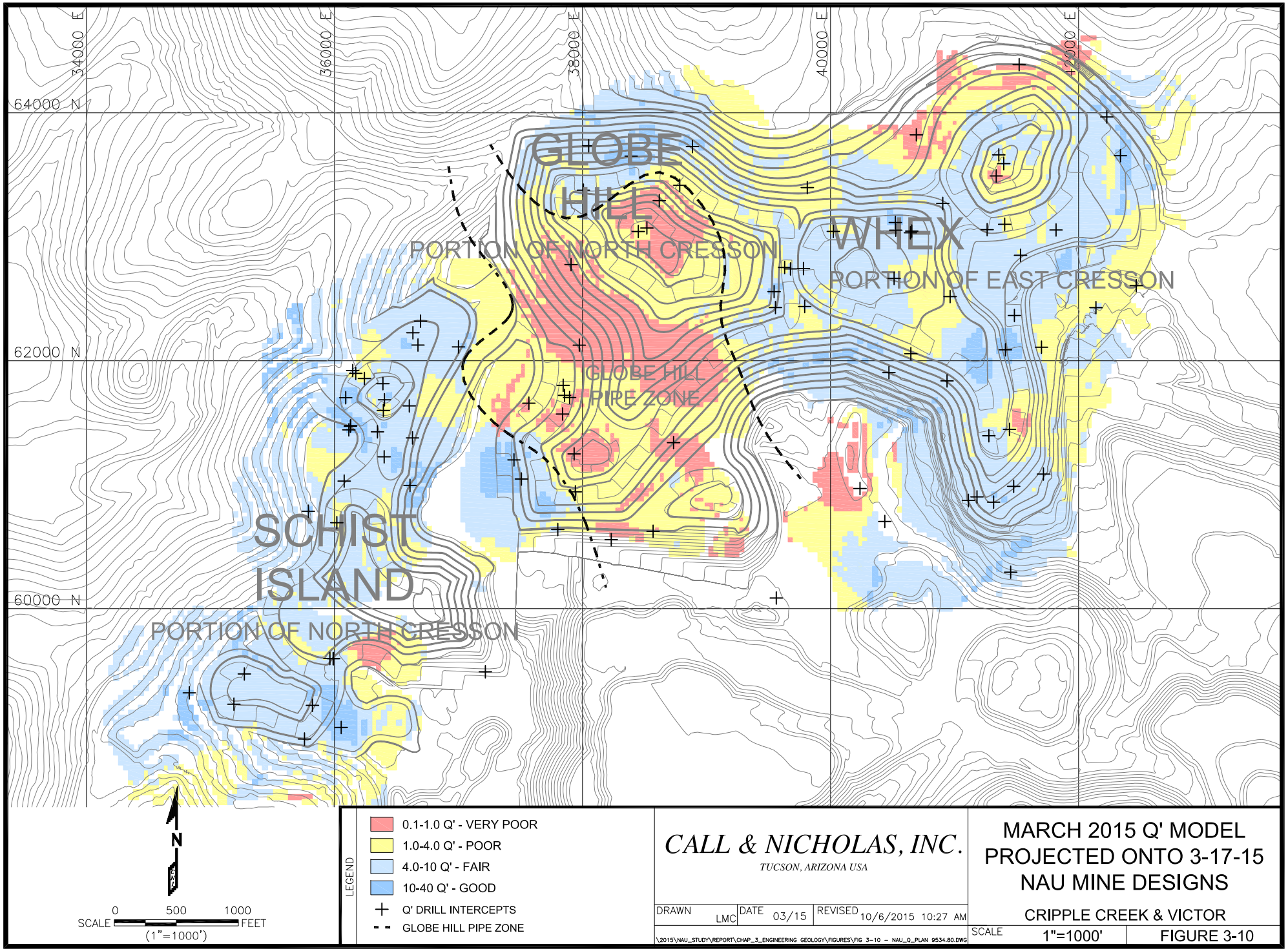
\2015\NAU_STUDY\REPORT\CHAP_3_ENGINEERING GEOLOGY\FIGURES\FIG 3-08 - WHEX_MAJOR_STRUCS.DWG

11/3/2015 12:42 AM

File:

Figure 3-8
Major Structure Mapping Data,
WHEX Mine


34000 E
36000 E
38000 E
40000 E
42000 E
64000 N
62000 N
60000 N
GLOBE HILL
PORTION OF NORTH CRESSON
WHITE X
PORTION OF EAST CRESSON
GLOBE HILL PIPE ZONE
SCHIST ISLAND
PORTION OF NORTH CRESSON
N
0 500 1000
SCALE FEET
(1"=1000')
LEGEND
0-20 RQD
20-40 RQD
40-60 RQD
60-80 RQD
80-100 RQD
RQD DRILL INTERCEPTS
GLOBE HILL PIPE ZONE
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DATE 03/15
REVISED 11/3/2015 12:43 AM
\2015\NAU_STUDY\REPORT\CHAP_3_ENGINEERING GEOLOGY\FIGURES\FIG 3-09 - RQD_PLAN 9720.18.DWG
MARCH 2015 RQD MODEL
PROJECTED ONTO 3-17-15
NAU MINE DESIGNS
CRIPPLE CREEK & VICTOR
SCALE 1"=1000'
FIGURE 3-9


34000 E
36000 E
38000 E
40000 E
42000 E
64000 N
62000 N
60000 N
GLOBE HILL
PORTION OF NORTH CRESSON
WHEX
PORTION OF EAST CRESSON
GLOBE HILL PIPE ZONE
SCHIST ISLAND
PORTION OF NORTH CRESSON
N
0
500
1000
SCALE
FEET
(1"=1000')
LEGEND
0.1-1.0 Q' - VERY POOR
1.0-4.0 Q' - POOR
4.0-10 Q' - FAIR
10-40 Q' - GOOD
Q' DRILL INTERCEPTS
GLOBE HILL PIPE ZONE
CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA
DRAWN LMC
DATE 03/15
REVISED 10/6/2015 10:27 AM
\2015\NAU_STUDY\REPORT\CHAP_3_ENGINEERING GEOLOGY\FIGURES\FIG 3-10 - NAU_Q_PLAN 9534.80.DWG
MARCH 2015 Q' MODEL
PROJECTED ONTO 3-17-15
NAU MINE DESIGNS
CRIPPLE CREEK & VICTOR
SCALE 1"=1000'
FIGURE 3-10

4.0 ROCK STRENGTH PARAMETERS

To evaluate slope stability and other geotechnical issues associated with the proposed NAU slope designs, laboratory testing is required to determine the shear strength of both the intact rock and the rock fractures for the various lithologic units encountered at Cripple Creek. Along with the intact shear strength and the fracture shear strength, the degree of rock fracturing and the orientation of the major fracture sets are required to estimate the rock-mass shear strength. Statistics are used to define the variability of the laboratory-defined strengths and the degree of fracturing. Variability of the rock mass strength determines the probability of failure for the analyzed slope geometry.

Selected core samples were tested at various labs, including the CNI rock mechanics laboratory. This was done to define the intact and shear strength characteristics for the geotechnical rock types that will constitute the final walls of the Cripple Creek NAU pits. Samples representative of the entire study area were selected to estimate the distribution of strengths within each rock type. Four types of laboratory strength tests were utilized to derive rock strengths for this study (Figure 4-1).

1. Small-scale direct-shear (SSDS)
2. Unconfined compressive strength (UCS)
3. Triaxial compression
4. Brazilian disc tension

A brief description of the testing and data reduction technique for each type of test performed is presented in this chapter. Raw data derived from laboratory testing must be reduced to provide estimates of the rock-strength properties to be used in the design. Strength summaries derived from these test results are listed as they were utilized in the analysis. Other tests that were performed include measurement of elastic properties with strain gauges, density testing, sieve analysis using the Unified Soil Classification System (USCS), and Atterberg Limits.

To perform stability analysis, it is necessary to define a reasonable number of material types that represent the major rock types present, both from a lithologic and geotechnical standpoint. Several igneous rock types are present at the Cripple Creek complex. The major igneous rock types identified by CCV geologists include the Cripple Creek breccia, phonolite

and lamprophyre. Additionally, Precambrian granite and schist form some of the slopes in the NAU pit designs.

4.1 Summary of Tests Performed

4.1.1 Unconfined Compression (UCS) Testing

UCS tests were performed on core samples relatively free of natural fractures. Core samples were cut to produce a sample with a length-to-diameter ratio of 2:1. The ends of the samples were ground flat, perpendicular to the core axis. The samples were then loaded axially without lateral confining load (σ_3=0) until the sample failed (Figure 4-1b). The maximum load at failure was recorded by a hydraulic pressure gauge. The maximum compressive strength (σ_1) is calculated by dividing this maximum load by the cross-sectional area of the sample. Uniaxial tests have been conducted on 43 Cripple Creek breccia samples, 5 lamprophyre samples, 41 phonolite samples, and 3 Precambrian schist samples. A tabular summary of all uniaxial compression tests is presented in Table 4-1.

4.1.2 Triaxial Compression Testing

Triaxial compression tests are similar to UCS tests except that a confining pressure (σ_3) is applied to the core sample (Figure 4-1b). The confining pressure is applied with a hydraulic pressure cell. The confining pressure is maintained as an axial load is applied to the sample, just as it is for the UCS tests. Triaxial tests were conducted on 20 Cripple Creek breccia samples, 5 lamprophyre samples, 11 phonolite samples and 5 Precambrian schist samples. A tabular summary of all triaxial compression tests is presented in Table 4-1.

Data reduction to determine the intact shear strength of the rock uses both unconfined and triaxial compression tests. Linear regression of the failure stress (σ_1) as a function of the confining stress (σ_3) and a stress transformation is used to calculate the intact shear strength in terms of the friction angle and the cohesion as show in Figure 4-2. The stresses are transformed from the principal stress space (σ_1, σ_3) to the shear stress-normal stress space (τ, σ_n).

4.1.3 Direct-Shear Testing

Small-scale direct-shear tests were performed on core samples with natural fractures or fault gouge. Samples were cut to fit the shear box, and then were fit into a mold using spacers to center the specimens to ensure the mean plane of the shear was as close as possible to the horizontal plane. Roughness and attitude measurements were then taken to correct for any deviation from horizontal.

The samples were mounted in a testing machine and a normal load was applied to the fracture surface (Figure 4-1a). This normal load is maintained while a shear load is applied to displace the sample along the fracture surface. The shear load is recorded on a shear versus displacement graph as the test proceeds (Figure 4-3). The residual shear strength of the fracture is attained when an increase in the shear displacement is not accompanied by a continued decrease in shear resistance. Each sample was tested at four different normal loads, resulting in several pairs of residual shear versus normal load graphs.

The contact area along the fracture surface was adjusted according to the amount of displacement. This was then divided into the normal and shear loads to obtain the normal and shear stress for each residual data point. Plots of shear stress versus normal stress were used to create linear and nonlinear regression lines which determined the sample's strength parameters.

The linear fit equation has the form:

$$\tau = c + \sigma_n \mu$$

Where:

τ = shear strength

c = cohesion

σ_n= normal stress

μ = coefficient of friction, where $\mu = tan\phi$ and ϕ is the friction angle

The power fit equation has the form:

$$\tau = K\sigma_n^{\,M}$$

Where:

τ = shear strength

K = curve parameter

σ_n = normal stress

M = curve parameter

The direct-shear testing consists of 7 Cripple Creek breccia samples, 7 phonolite samples, 4 lamprophyre samples, 4 Precambrian schist samples, 3 rubble samples from the WHEX pit, and 2 fault gouge samples. A tabular summary of the direct-shear tests is presented in Table 4-2.

4.1.4 Brazilian Disc Tension Testing

Brazilian disc tension tests were performed on core samples relatively free of natural fractures. Core samples were cut to a thickness-to-diameter ratio of approximately 0.5:1. These thin, disc-shaped samples can usually be obtained from trimmed core left over from preparing the UCS or triaxial samples. This test consists of diametrically loading the disc of core until it splits (Figure 4-1c).

The vertical load at failure is noted when the disc shows visible cracking. The sample tensile strength is calculated using the formula:

$$T_0 = 2P_f/\pi dh$$

Where:

T_0 = tensile strength

P_f = vertical load at failure

d = disc diameter

h = disc thickness

The intact rock is assigned the tensile strength from the test unless the sample fails in a direction other than the direction of loading. Results of the Brazilian disc tension tests are summarized in Table 4-1.

4.1.5 Soil Classification Testing

CNI utilizes the Unified Soil Classification System (USCS) to determine the expected behavior of soils. The basis of soil classification is that coarse-grained soils are classified according the distribution of their grain sizes, whereas fine-grained soils are classified based on their plasticity. The only required tests to determine these characteristics are the sieve analysis

and Atterberg limits test. The sieve analysis passes a known weight of soil sample over a series of sieves, and the percentage of the sample that is retained on each sieve determines the grain-size distribution. The Atterberg limits tests only the fines portion of the soil that passed the No. 200 sieve (0.074 mm) is used to determine the water contents at which the soil changes its behavior state: solid, semi-solid, plastic, and liquid. One of the most important properties derived from the Atterberg test is the plasticity index (PI), which is the range of water contents over which the soil exhibits plastic properties (defined as the difference between the liquid limit and plastic limit, i.e. PI = LL-PL). The PI is considered an indicator property that is correlated with the shear strength and swelling potential of a fine-grained soil.

Soils that have been classified at CCV include fault gouge from the Cripple Creek breccia, WHEX colluvium, and the shattered low RQD material from the Globe Hill pipe. Gradation curves and Atterberg limits results are presented in Figure 4-4. The soils at CCV are generally classified as well-graded sands and gravels with a small percentage of low plasticity fines.

4.2 Strength Regressions

4.2.1 Intact Rock Properties

A summary of intact rock material properties derived from the testing described in the preceding sections is presented in Table 4-3. To generate this summary table, data were combined from all laboratory testing campaigns. Data include intact material strength based on UCS and triaxial testing for the Cripple Creek breccia, phonolite, lamprophyre, and Precambrian schist. Intact testing regressions that estimate the intact rock cohesion and friction angle are plotted in Figures 4-5 through 4-9.

4.2.2 Fracture Shear Strength (Used in Bench-Scale Analysis and Rock Strength Estimates)

A summary of the combined linear and power fracture shear strengths derived from direct-shear testing is presented in Table 4-4. The fracture shear strengths are used in the bench-scale analysis because the primary mode of bench failure is through preexisting fractures. The linear regressions for all rock types tested are presented in Figures 4-10 thru 4-15.

Fracture shear strength is also an input used for estimating the rock mass shear strength.

4.3 Summary of Recent Laboratory Testing Campaigns

The last comprehensive testing summary was completed for CCV in 2011 as part of the MLE2 slope design study. Since the MLE2 study, three minor testing programs have been completed to support ongoing geotechnical work at the mine.

4.3.1 White Cripple Creek Breccia

An altered zone in the Cripple Creek breccia was identified by CCV geologists in 2012 on the south end of the east wall in the Cresson pit. This altered zone is characterized by a white to grey color, blocky fragmentation, elevated clay content, and high drilling rates. This zone contains a pit-ward dipping joint set that causes excessive backbreak of the bench crests. The approximate dip of this set is 45° with lengths greater than 20 feet. A boulder grab sample of the white breccia was cored at the CNI rock mechanics laboratory. Four uniaxial tests were performed (two with strain gages to measure elastic properties) on the white breccia core samples to determine if this sub-type of Cripple Creek breccia presents different shear strength properties than typical breccia. The white breccia was found to have a similar uniaxial strength to that of typical Cripple Creek breccia, and the stiffness (Young's modulus) was found to be about 25 percent lower.

4.3.2 Precambrian Schist

Laboratory tests were performed on Precambrian schist core samples from hole GT13-1 located in the WHEX mine. These were the first geotechnical laboratory tests of the schist. Three uniaxial tests, five triaxial tests, and four small-scale direct-shear tests were performed on the schist in order to characterize its shear strength.

4.3.3 Globe Hill Pipe Low RQD Zone

Core drilling has identified a large zone of altered and weak rock mass that cuts through the Globe Hill area. This zone can be seen in the plots of the RQD and Q' block models exposed on the walls of the NAU mine designs that were presented in Figures 3-9 and 3-10. Photos of core from hole GT11-04, which is typical of this zone, are shown in Figure 4-16. Geotechnical core samples were sent to CNI in order to better classify the zone in an effort to update the rock mass strength estimations in this area for the NAU study. Laboratory tests performed include

four triaxial and two disc tension tests performed on soild rock core intervals just outside of the Globe Hill pipe zone, and three soil classification and one direct-shear remold test performed on the Globe Hill pipe material. Soil classification tests show that the Globe Hill pipe is composed of high friction, low cohesion, non-plastic gravels. Lab sheets for the Globe Hill Pipe tests are compiled in Appendix D.

The shear strength of the Globe Hill pipe zone was estimated based on previous experience in similar type materials. It is very difficult if not impossible to directly measure the shear strength of a lightly cemented, interlocked, non-plastic gravel such as the Globe Hill pipe; the material cannot be tested accurately in a large scale direct shear or triaxial cell because the particle size is too large, and the material cannot be sampled or cored without disturbing it and breaking up the particle interlock. A power relation was used to model the shear strength with the form $\tau=K*\sigma_n^m$, where K=1.707 (for σ_n in psi) and m=0.846. This strength relation can be seen in Figure 4-17 compared to shear strengths utilized for similar type materials at other mines. Also shown in the figure is an inset table with the secant friction angle of the proposed strength relation for various normal stresses.

4.4 Rock-Mass Properties (Used in Global Slope Analysis)

Rock-mass behavior depends on characteristics of the intact rock as well as characteristics of fractures within the rock mass. Rock-mass properties are very difficult to measure directly because of the sample size that would be required for testing. Therefore, rock-mass properties are usually estimated using methods that relate the properties to the more easily measured intact rock and fracture properties.

CNI developed a post-peak rock-mass strength estimation method that uses measurable laboratory data including the intact rock strength and the fracture strength. Combined with field-measured RQD data, the final CNI rock-mass post peak strength estimations are based on back-analyses of multi bench-scale historical failures. The approach for this strength estimation method can be found in the SME paper, “Managing and Analyzing Overall Pit Slopes” (*Slope Stability in Surface Mining,* 2000), and is summarized in the following paragraphs.

Along with the intact rock shear strength and the fracture shear strength, the rock-mass shear strength is a function of the size of the intact blocks of rock that are bounded by fractures, and the orientation of the fractures. Therefore, rock-mass strength, which is bracketed between

the fracture and intact shear strength of the tested samples, can be determined by estimating a strength reduction factor which is related to the block size. CNI uses the rock quality designation (RQD) to estimate the block size of the rock mass. Back-analyses of both open-pit and underground failures, as well as fracture modeling studies of a rock mass, indicate rock-mass strength can be related to the ratio between the rock mass and the intact rock moduli. The modulus ratio is a function of RQD, as discussed below.

To determine the elastic modulus (Young's Modulus) for a rock mass, Bieniawski (1978) proposed the following relationship for the correlation between RQD and the ratio of rock-mass modulus to intact rock elastic modulus:

$$r = E_{mass}/E_{intact} = \alpha e^{\beta(\%RQD)}$$

Where:

E_{mass} = rock-mass deformation modulus

E_{intact} = intact rock deformation modulus

α, β = constants

%RQD = average RQD of rock mass

Deere and Miller (1966) demonstrated that the elastic modulus for intact rock can be related to the intact compressive strength, and defined a narrow range of observed ratios between elastic modulus and compressive strength for both brittle and soft rock materials. Consequently, it seems reasonable to expect there may be a similar relationship between the rock-mass modulus and rock-mass strength. Back-analysis of slope failures indicated the estimation of rock-mass strength does follow Bieniawski's relationship for predicting deformation modulus; however, the strength properties were found to vary according to the square of the modulus ratio (r^2). For example, if the square of the modulus ratio is 0.3, the estimated rock-mass strength can be derived by compositing 30 percent of the intact rock strength with 70 percent of the joint strength.

The resulting equations for predicting the rock-mass friction angle and cohesion are:

$$C_m = \gamma[(r_c)^2 c_i + (1-(r_c)^2)\, c_j]$$

$$\phi_m = \tan^{-1}\,[(r_\phi)2\,\tan(\phi_i) + 1-(r_\phi)^2)\,\tan(\phi_j)]$$

Where:

$r_\phi = 0.3775e^{0.0075(\%RQD)}$

$r_c = 0.2250e^{0.0130(\%RQD)}$

$0.5 \leq \gamma \leq 1.0$

$\gamma = 0.5$ for jointed medium-to-strong intact rock (UCS >60 Mpa)

$\gamma = 1.0$ for massive weak-to-very weak intact rock (UCS <15 Mpa)

and:

ϕ_m = rock-mass friction angle

C_m = rock-mass cohesion

ϕ_i = intact rock friction angle

c_i = intact rock cohesion

ϕ_j = joint friction angle

c_j = joint cohesion

For simplicity, the rock-mass strength equations presented here apply only to a linear Mohr-Coulomb strength envelope. The strength curve can be converted to a power envelope by applying regression techniques using calculated percentage of intact rock ($r^2 * 100$) and the power strength envelopes for the intact rock and joint strength data.

A cohesion reduction factor, γ, is applied to the rock mass cohesion calculation. Intact compressive strength exerts the primary control on the constant gamma (γ). However, γ is also influenced by the degree of fracturing in the rock mass. In general, γ increases as the intact compressive strength decreases, and it increases as the degree of fracturing increases.

The CNI rock-mass strength method has been successfully used for open-pit slope design for more than 30 years. However, the Hoek-Brown rock-mass strength estimation method is the most commonly used method in geotechnical practice. It is often useful to compare different methods of rock-mass strength estimation in order to gain a greater understanding of the possible range of values. For example, Wiles (2006) estimates that the coefficient of variation for rock-mass strength estimation may be 25 to 35 percent. Hoek-Brown strengths were generated for the complete range of rock types and RQD values in unison with the CNI rock mass strength estimation method. Comparison charts of the CNI rock-mass strength estimation method and the Hoek-Brown method are presented in Appendix E. The disturbance factor, D, was assumed to

equal 0.7 for the Hoek-Brown method. For example, Figure 4-18 shows the CNI rock-mass strength estimation method compared to the Hoek Brown rock-mass strength estimation method for Cripple Creek breccia with an RQD of 90 percent and 70 percent.

The mean rock-mass strength parameters for the NAU study are presented in Table 4-5.

Table 4-1. Intact Rock Strength Testing Summary (1 of 3)

Updated SEP 2015		Sample Details								Rock Properties			Compression/Tension Testing (σ_1/σ_3 Space)							
Test Source	Test Year	Sample Type	Sample Size (in) diameter	length	L/D Ratio	Sample Number	Hole Number	Sample Depth (ft)	Field Location (mine)	Test Type	Site Lithologic Descriptors Abbrev	Lithology	Density (pcf)	Peak Test σ1 (cor) (psi)	σ3 (psi)	Disc Tensile (psi)	Disc Ratio	Failure Condition Uniax/Triax	Failure Condition Disc	Young's Modulus (psi)	Poisson's Ratio
CNI	1994	Core	2.399	4.934	2.06	CC93-63-331	**CC-93-63**	330.7	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	142.0	14,432	---	---	---	Intact	---	---	---
CNI	1994	Core	2.401	4.884	2.03	CC-93-63-482	**CC-93-63**	482.0	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	151.0	15,054	---	---	---	Intact	---	---	---
CNI	1994	Core	2.403	4.903	2.04	CC-93-65-379	**CC-93-65**	379.1	SE Cresson	Uniax	**TBX**	Cripple Creek Breccia	151.0	11,539	---	---	---	Intact	---	---	---
CNI	1994	Core	2.397	4.847	2.02	CC-93-64-632	**CC-92-64-2**	632.2	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	139.0	7,093	---	---	---	Both	---	---	---
CNI	1994	Core	2.399	4.819	2.01	CC-93-64-567	**CC-93-64**	567.2	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	137.0	5,757	---	---	---	Fracture	---	---	---
CNI	1994	Core	2.398	4.881	2.04	CC-93-65-255	**CC-93-65**	255.2	SE Cresson	Uniax	**TBX**	Cripple Creek Breccia	140.0	5,502	---	---	---	Both	---	---	---
???	1998	Core	---	---	---	CC98-88-680	**CC98-88**	680.0	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	14,900	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-86-677	**CC98-86**	677.2	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	6,590	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-88-784	**CC98-88**	784.4	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	12,120	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-89-552	**CC98-89**	552.0	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	6,510	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-89-703	**CC98-89**	703.0	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	7,780	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-85-685	**CC98-85**	685.3	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	48,050	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-85-561	**CC98-85**	561.4	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	12,740	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-85-650	**CC98-85**	650.0	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	14,440	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-90-917	**CC98-90**	917.5	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	4,130	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-82-1048	**CC98-82**	1048.5	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	9,050	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-83-1191	**CC98-83**	1191.4	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	6,230	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-82-995	**CC98-82**	995.4	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	15,240	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-83-1098	**CC98-83**	1098.2	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	15,860	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-83-985	**CC98-83**	985.0	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	9,430	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-82-1034	**CC98-82**	1034.0	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	8,460	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-83-852	**CC98-83**	852.0	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	7,330	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-82-1060	**CC98-82**	1060.8	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	20,730	---	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT99-3B-a	**GT99-3**	---	W Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	11,600	---	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT99-2B-a	**GT99-2**	---	W Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	10,030	---	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT99-1B-a	**GT99-1**	---	W Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	8,430	---	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT98-1B-a	**GT98-1**	---	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	---	12,690	---	---	---	---	---	---	---
CNI	2006	Core	2.500	4.849	1.94	949-0101-367	**GT-01-01**	367.5	???	Uniax	**TBX**	Cripple Creek Breccia	149.5	5,985	---	1,600	3.74	Intact	---	---	---
CNI	2006	Core	2.506	4.869	1.94	949-0101-469	**GT-01-01**	469.8	???	Uniax	**TBX**	Cripple Creek Breccia	152.0	18,542	---	1,328	13.96	Intact	---	---	---
CNI	2006	Core	2.410	4.864	2.02	949-981-1202	**GT-98-1**	1202.2	SE Cresson	Uniax	**TBX**	Cripple Creek Breccia	152.3	12,139	---	1,078	11.26	Intact	---	---	---
CNI	2006	Core	2.412	4.839	2.01	949-981-1222	**GT-98-1**	1222.3	SE Cresson	Uniax	**TBX**	Cripple Creek Breccia	149.0	12,232	---	1,056	11.58	Intact	---	---	---
CNI	2006	Core	2.396	4.864	2.03	949-981-1301	**GT-98-1**	1301.5	SE Cresson	Uniax	**TBX**	Cripple Creek Breccia	154.7	19,422	---	1,292	15.03	Intact	---	---	---
CNI	2009	Core	2.393	3.991	1.67	421-GT-09-02-456	**GT-09-02**	456.8	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	154.3	1,969	---	898	2.19	Fracture	Both	1.70E+06	0.11
CNI	2009	Core	2.393	4.497	1.88	421-GT-09-02-480-U	**GT-09-02**	480.1	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	151.4	4,634	---	159	29.14	Intact	Fracture	2.13E+06	0.20
CNI	2009	Core	2.402	4.824	2.01	421-GT-09-02-490	**GT-09-02**	490.0	E Cresson	Uniax	**TBX**	Cripple Creek Breccia	164.7	22,969	---	---	---	Intact	---	7.98E+06	0.24
CNI	2010	Core	2.374	4.891	2.06	455-GT10-5-0152	**GT10-5**	152.0	N WHEX	Uniax	**TBX**	Cripple Creek Breccia	138.9	7,482	---	---	---	Intact	---	---	---
CNI	2010	Core	2.386	4.733	1.98	455-GT10-5-0347	**GT10-5**	347.6	N WHEX	Uniax	**TBX**	Cripple Creek Breccia	137.1	3,798	---	912	4.16	Fracture	Both	---	---
CNI	2010	Core	2.415	4.778	1.98	455-GT10-5-0571	**GT10-5**	571.0	N WHEX	Uniax	**TBX**	Cripple Creek Breccia	128.9	654	---	323	2.02	Both	Both	---	---
CNI	2010	Core	2.404	4.823	2.01	455-GT10-5-0631	**GT10-5**	631.2	N WHEX	Uniax	**TBX**	Cripple Creek Breccia	132.0	602	---	412	1.46	Both	Both	---	---
Itasca	2001	Core	---	---	---	GT99-3B-b	**GT99-3**	---	W Cresson	Triax	**TBX**	Cripple Creek Breccia	---	18,760	1,450	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT99-3B-c	**GT99-3**	---	W Cresson	Triax	**TBX**	Cripple Creek Breccia	---	23,390	2,900	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT99-2B-b	**GT99-2**	---	W Cresson	Triax	**TBX**	Cripple Creek Breccia	---	14,080	1,080	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT99-2B-c	**GT99-2**	---	W Cresson	Triax	**TBX**	Cripple Creek Breccia	---	19,420	2,180	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT99-1B-b	**GT99-1**	---	W Cresson	Triax	**TBX**	Cripple Creek Breccia	---	15,850	1,090	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT99-1B-c	**GT99-1**	---	W Cresson	Triax	**TBX**	Cripple Creek Breccia	---	18,900	2,180	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT98-1B-b	**GT98-1**	---	E Cresson	Triax	**TBX**	Cripple Creek Breccia	---	23,170	1,630	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT98-1B-c	**GT98-1**	---	E Cresson	Triax	**TBX**	Cripple Creek Breccia	---	30,980	3,260	---	---	---	---	---	---
CNI	2009	Core	2.399	4.816	2.01	421-GT-09-02-407	**GT-09-02**	407.4	E Cresson	Triax	**TBX**	Cripple Creek Breccia	148.1	4,427	400	414	---	Both	Both	---	---
CNI	2009	Core	2.394	4.865	2.03	421-GT-09-02-445	**GT-09-02**	445.0	E Cresson	Triax	**TBX**	Cripple Creek Breccia	151.6	12,687	1,600	346	---	Both	Both	---	---
CNI	2009	Core	2.402	4.764	1.98	421-GT-09-02-460	**GT-09-02**	460.4	E Cresson	Triax	**TBX**	Cripple Creek Breccia	149.9	10,806	1,600	318	---	Both	Both	---	---
CNI	2009	Core	2.390	4.780	2.00	421-GT-09-02-480-T	**GT-09-02**	480.1	E Cresson	Triax	**TBX**	Cripple Creek Breccia	150.5	12,710	1,600	---	---	Both	---	---	---
CNI	2009	Core	2.394	4.707	1.97	421-GT-09-02-481	**GT-09-02**	481.1	E Cresson	Triax	**TBX**	Cripple Creek Breccia	160.9	23,724	400	1,633	---	Both	Intact	---	---
CNI	2009	Core	2.398	4.842	2.02	421-GT-09-02-493	**GT-09-02**	493.2	E Cresson	Triax	**TBX**	Cripple Creek Breccia	166.3	30,821	800	2,004	---	Intact	Intact	---	---
CNI	2009	Core	2.389	4.957	2.07	421-GT-09-03-983	**GT-09-03**	983.0	E Cresson	Triax	**TBX**	Cripple Creek Breccia	155.5	31,362	500	2,315	---	Intact	Intact	---	---
CNI	2009	Core	2.382	4.968	2.09	421-GT-09-03-1023	**GT-09-03**	1023.0	E Cresson	Triax	**TBX**	Cripple Creek Breccia	155.4	34,035	3,000	1,609	---	Both	Both	---	---

Table 4-1. Intact Rock Strength Testing Summary (2 of 3)

Updated SEP 2015		Sample Details								Rock Properties			Compression/Tension Testing (σ_1/σ_3 Space)							
Test Source	Test Year	Sample Type	Sample Size (in) diameter	length	L/D Ratio	Sample Number	Hole Number	Sample Depth (ft)	Field Location (mine)	Test Type	Site Lithologic Descriptors Abbrev	Lithology	Density (pcf)	Peak Test σ1 (cor) (psi)	σ3 (psi)	Disc Tensile (psi)	Disc Ratio	Failure Condition Uniax/Triax	Failure Condition Disc	Young's Modulus (psi)	Poisson's Ratio
CNI	2009	Core	2.384	5.021	2.11	421-GT-09-03-1066	GT-09-03	1066.4	E Cresson	Triax	TBX	Cripple Creek Breccia	152.5	25,235	500	1,630	---	Intact	Intact	---	---
CNI	2009	Core	2.385	4.997	2.10	421-GT-09-03-1096	GT-09-03	1096.7	E Cresson	Triax	TBX	Cripple Creek Breccia	160.9	60,763	3,000	1,848	---	Intact	Intact	---	---
CNI	2009	Core	2.384	5.006	2.10	421-GT-09-03-1116	GT-09-03	1116.5	E Cresson	Triax	TBX	Cripple Creek Breccia	155.6	18,697	500	1,506	---	Intact	Intact	---	---
CNI	2009	Core	2.394	4.969	2.08	421-GT-09-03-1126	GT-09-03	1126.5	E Cresson	Triax	TBX	Cripple Creek Breccia	155.5	52,414	3,000	1,967	---	Intact	Intact	---	---
???	1998	Core	---	---	---	CC98-88-655	CC98-88	655.0	E Cresson	Uniax	HBX	Hydro Breccia	---	16,140	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-84-987	CC98-84	987.5	E Cresson	Uniax	HBX	Hydro Breccia	---	9,000	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-85-994	CC98-85	994.5	E Cresson	Uniax	HBX	Hydro Breccia	---	7,990	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-81-1254	CC98-81	1254.3	E Cresson	Uniax	HBX	Hydro Breccia	---	12,160	---	---	---	---	---	---	---
CNI	2009	Surface	2.322	4.619	1.99	421-BLK-LMP-U1	---	9515	Cresson	Uniax	TLU	Lamprophyre	178.9	20,774	---	809	25.68	Intact	Intact	7.64E+06	0.21
CNI	2009	Surface	2.332	3.922	1.68	421-BLK-LMP-U2	---	9515	Cresson	Uniax	TLU	Lamprophyre	176.1	10,691	---	1,253	8.53	Intact	Intact	5.78E+06	0.23
CNI	2009	Surface	2.323	3.942	1.70	421-BLK-LMP-U3	---	9515	Cresson	Uniax	TLU	Lamprophyre	169.8	7,965	---	1,174	6.78	Intact	Intact	2.09E+06	--
CNI	2009	Surface	2.333	3.235	1.39	421-BLK-LMP-U4	---	9515	Cresson	Uniax	TLU	Lamprophyre	176.7	7,216	---	1,221	5.91	Both	Intact	3.05E+06	0.22
CNI	2009	Surface	2.331	4.308	1.85	421-BLK-LMP-U5	---	9515	Cresson	Uniax	TLU	Lamprophyre	175.6	9,052	---	1,174	7.71	Intact	Intact	3.21E+06	0.11
CNI	2009	Surface	2.332	4.373	1.88	421-BLK-LMP-T1	---	9515	Cresson	Triax	TLU	Lamprophyre	171.5	4,415	200	848	---	Both	Both	---	---
CNI	2009	Surface	2.332	4.618	1.98	421-BLK-LMP-T2	---	9515	Cresson	Triax	TLU	Lamprophyre	173.5	7,015	400	867	---	Intact	Intact	---	---
CNI	2009	Surface	2.332	4.552	1.95	421-BLK-LMP-T3	---	9515	Cresson	Triax	TLU	Lamprophyre	171.6	13,070	800	942	---	Both	Intact	---	---
CNI	2009	Surface	2.323	4.582	1.97	421-BLK-LMP-T4	---	9515	Cresson	Triax	TLU	Lamprophyre	170.2	15,543	1,600	858	---	Intact	Intact	---	---
CNI	2009	Surface	2.330	4.567	1.96	421-BLK-LMP-T5	---	9515	Cresson	Triax	TLU	Lamprophyre	169.3	12,162	1,600	1,465	---	Both	Intact	---	---
IES	1998	Core	---	---	---	ALTGT01-85	ACGT97-1	85.9	Altman	Uniax	TPH	Phonolite	---	12,590	---	---	---	---	---	---	---
IES	1998	Core	---	---	---	ALTGT01-228	ACGT97-1	228.0	Altman	Uniax	TPH	Phonolite	---	14,930	---	---	---	---	---	---	---
IES	1998	Core	---	---	---	ALTGT01-305	ACGT97-1	305.0	Altman	Uniax	TPH	Phonolite	---	17,730	---	---	---	---	---	---	---
IES	1998	Core	---	---	---	ALTGT01-401	ACGT97-1	401.0	Altman	Uniax	TPH	Phonolite	---	29,130	---	---	---	---	---	---	---
IES	1998	Core	---	---	---	ALTGT01-466	ACGT97-1	466.0	Altman	Uniax	TPH	Phonolite	---	4,360	---	---	---	---	---	---	---
IES	1998	Core	---	---	---	ALTGT01-482	ACGT97-1	482.0	Altman	Uniax	TPH	Phonolite	---	3,460	---	---	---	---	---	---	---
IES	1998	Core	---	---	---	ALTGT02-55	ACGT97-2	55.0	Altman	Uniax	TPH	Phonolite	---	6,610	---	---	---	---	---	---	---
IES	1998	Core	---	---	---	ALTGT02-56	ACGT97-2	56.0	Altman	Uniax	TPH	Phonolite	---	4,960	---	---	---	---	---	---	---
IES	1998	Core	---	---	---	ALTGT02-80	ACGT97-2	80.0	Altman	Uniax	TPH	Phonolite	---	6,030	---	---	---	---	---	---	---
IES	1998	Core	---	---	---	ALTGT02-250	ACGT97-2	250.0	Altman	Uniax	TPH	Phonolite	---	9,340	---	---	---	---	---	---	---
IES	1998	Core	---	---	---	ALTGT02-336	ACGT97-2	336.0	Altman	Uniax	TPH	Phonolite	---	1,540	---	---	---	---	---	---	---
IES	1998	Core	---	---	---	ALTGT02-411	ACGT97-2	411.0	Altman	Uniax	TPH	Phonolite	---	16,310	---	---	---	---	---	---	---
IES	1998	Core	---	---	---	ALTGT03-87	ACGT97-3	87.0	Altman	Uniax	TPH	Phonolite	---	23,490	---	---	---	---	---	---	---
IES	1998	Core	---	---	---	ALTGT03-382	ACGT97-3	382.0	Altman	Uniax	TPH	Phonolite	---	3,080	---	---	---	---	---	---	---
IES	1998	Core	---	---	---	ALTGT03-543	ACGT97-3	543.0	Altman	Uniax	TPH	Phonolite	---	9,220	---	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT99-3P-a	GT99-3	---	W Cresson	Uniax	TPH	Phonolite	---	12,590	---	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT99-1P-a	GT99-1	---	W Cresson	Uniax	TPH	Phonolite	---	4,360	---	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT98-1P-a	GT98-1	---	E Cresson	Uniax	TPH	Phonolite	---	8,050	---	---	---	---	---	---	---
CNI	2006	Core	2.505	4.910	1.96	949-0101-409	GT-01-01	409.5	???	Uniax	TPH	Phonolite	161.7	26,321	---	2,424	10.86	Both	---	---	---
CNI	2006	Core	2.505	4.851	1.94	949-0101-420	GT-01-01	420.6	???	Uniax	TPH	Phonolite	163.9	37,386	---	2,756	13.57	Intact	---	---	---
CNI	2006	Core	2.501	4.835	1.93	949-0101-519	GT-01-01	519.5	???	Uniax	TPH	Phonolite	152.1	8,516	---	1,679	5.07	Fracture	---	---	---
CNI	2006	Core	2.502	4.868	1.95	949-0101-568	GT-01-01	568.8	???	Uniax	TPH	Phonolite	145.3	9,528	---	1,047	9.10	Fracture	---	---	---
CNI	2006	Core	2.502	4.813	1.92	949-0101-650	GT-01-01	650.0	???	Uniax	TPH	Phonolite	145.8	5,972	---	1,286	4.64	Intact	---	---	---
CNI	2009	Core	2.381	4.828	2.03	421-GT-09-04-637	GT-09-04	637.3	E Cresson	Uniax	TPH	Phonolite	158.9	17,812	---	---	---	Intact	---	7.88E+06	0.26
Itasca	2001	Core	---	---	---	GT99-3P-b	GT99-3	---	W Cresson	Triax	TPH	Phonolite	---	19,170	1,630	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT99-3P-c	GT99-3	---	W Cresson	Triax	TPH	Phonolite	---	29,200	3,260	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT99-1P-b	GT99-1	---	W Cresson	Triax	TPH	Phonolite	---	6,410	730	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT99-1P-c	GT99-1	---	W Cresson	Triax	TPH	Phonolite	---	11,010	1,450	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT98-1P-b	GT98-1	---	E Cresson	Triax	TPH	Phonolite	---	21,810	1,090	---	---	---	---	---	---
Itasca	2001	Core	---	---	---	GT98-1P-c	GT98-1	---	E Cresson	Triax	TPH	Phonolite	---	17,240	2,180	---	---	---	---	---	---
CNI	2009	Core	2.385	4.963	2.08	421-GT-09-01-400	GT-09-01	400.7	E Cresson	Triax	TPH	Phonolite	151.5	36,871	500	1,495	---	Intact	Intact	---	---
CNI	2009	Core	2.404	4.766	1.98	421-GT-09-02-201	GT-09-02	201.4	E Cresson	Triax	TPH	Phonolite	159.0	17,378	500	---	---	Both	---	---	---
CNI	2009	Core	2.396	4.982	2.08	421-GT-09-02-211	GT-09-02	211.0	E Cresson	Triax	TPH	Phonolite	161.0	18,709	500	806	---	Both	Fracture	---	---
CNI	2009	Core	2.398	4.906	2.05	421-GT-09-02-213	GT-09-02	213.3	E Cresson	Triax	TPH	Phonolite	158.3	60,376	3,000	2,321	---	Intact	Intact	---	---
CNI	2009	Core	2.389	4.507	1.89	421-GT-09-04-627	GT-09-04	627.9	E Cresson	Triax	TPH	Phonolite	157.0	62,259	3,000	2,039	---	Intact	Intact	---	---
CNI	1994	Core	2.399	4.884	2.04	CC-93-63-321	CC-93-63	321.4	E Cresson	Uniax	TPHd	Phonolite, Aphanitic Dike	145.0	8,627	---	---	---	Fracture	---	---	---
CNI	1994	Core	2.400	4.864	2.03	CC-93-64-238	CC-93-64	238.0	E Cresson	Uniax	TPHd	Phonolite, Aphanitic Dike	158.0	28,339	---	---	---	Intact	---	---	---

Table 4-1. Intact Rock Strength Testing Summary (3 of 3)

Updated SEP 2015		Sample Details									Rock Properties			Compression/Tension Testing (σ_1/σ_3 Space)							
Test Source	Test Year	Sample Type	Sample Size (in) diameter	Sample Size (in) length	Sample Size (in) L/D Ratio	Sample Number	Hole Number	Sample Depth (ft)	Field Location (mine)	Test Type	Site Lithologic Descriptors Abbrev	Site Lithologic Descriptors Lithology	Density (pcf)	Peak Test σ1 (cor) (psi)	Peak Test σ3 (psi)	Disc Tensile (psi)	Disc Ratio	Failure Condition Uniax/Triax	Failure Condition Disc	Young's Modulus (psi)	Poisson's Ratio
???	1998	Core	---	---	---	CC98-85-832	**CC98-85**	832.4	E Cresson	Uniax	**TPHkm**	Phonolite, Mega-Crystic	---	31,290	---	---	---	---	---	---	---
CNI	1994	Core	2.400	4.810	2.00	CC-93-64-390	**CC-93-64**	390.0	E Cresson	Uniax	**TPHk**	Phonolite, Porphyritic	157.0	14,817	---	---	---	Fracture	---	---	---
CNI	1994	Core	2.349	4.960	2.11	CC-93-64-607	**CC-93-64**	607.4	E Cresson	Uniax	**TPHk**	Phonolite, Porphyritic	143.0	9,122	---	---	---	Fracture	---	---	---
CNI	1994	Core	2.398	4.915	2.05	CC-93-63-218	**CC-93-63**	217.5	E Cresson	Uniax	**TPHk**	Phonolite, Porphyritic	144.0	10,724	---	---	---	Fracture	---	---	---
CNI	1994	Core	2.397	4.875	2.03	CC-93-63-181	**CC-93-63**	181.2	E Cresson	Uniax	**TPHk**	Phonolite, Porphyritic	142.0	11,323	---	---	---	Intact	---	---	---
CNI	1994	Core	2.400	4.863	2.03	CC-93-63-265	**CC-93-63**	265	E Cresson	Uniax	**TPHk**	Phonolite, Porphyritic	150.0	11,716	---	---	---	Intact	---	---	---
CNI	1994	Core	2.403	4.950	2.06	CC-93-64-308	**CC-93-64**	307	E Cresson	Uniax	**TPHk**	Phonolite, Porphyritic	143.0	7,646	---	---	---	Fracture	---	---	---
???	1998	Core	---	---	---	CC98-81-1195	**CC98-81**	1195.0	E Cresson	Uniax	**TPHk**	Phonolite, Porphyritic	---	9,960	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-85-596	**CC98-85**	596.0	E Cresson	Uniax	**TPHk**	Phonolite, Porphyritic	---	24,170	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-84-1058	**CC98-84**	1058.0	E Cresson	Uniax	**TPHk**	Phonolite, Porphyritic	---	16,480	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-84-1049	CC98-84	1050	E Cresson	Uniax	**TPHk**	Phonolite, Porphyritic	---	7,920	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-85-923	CC98-85	924	E Cresson	Uniax	**TPHk**	Phonolite, Porphyritic	---	40,510	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-86-717	CC98-86	717	E Cresson	Uniax	**TPHk**	Phonolite, Porphyritic	---	26,910	---	---	---	---	---	---	---
???	1998	Core	---	---	---	CC98-89-657	CC98-89	657	E Cresson	Uniax	**TPHk**	Phonolite, Porphyritic	---	32,840	---	---	---	---	---	---	---
CNI	2009	Core	2.388	4.806	2.01	421-GT-09-04-280	GT-09-04	280	E Cresson	Uniax	**TPH Kbx**	Phonolite-matrix Breccia	140.0	8,691	---	---	---	Both	---	2.85E+06	0.22
CNI	2012	Core	2.328	4.855	2.09	452-CCV-SE-3	GRAB	--	SE Cresson	Uniax	**TBX-W**	CC Breccia (Altered White)	149.3	11,729	---	---	---	Intact	---	2.82E+06	0.44
CNI	2012	Core	2.328	4.820	2.07	452-CCV-SE-4	GRAB	--	SE Cresson	Uniax	**TBX-W**	CC Breccia (Altered White)	149.5	8,446	---	---	---	Intact	---	---	---
CNI	2012	Core	2.32	4.80	2.07	452-CCV-SE-5	**GRAB**	--	SE Cresson	Uniax	**TBX-W**	CC Breccia (Altered White)	149.65	6,163	---	---	---	Intact	---	---	---
CNI	2012	Core	2.32	4.83	2.08	452-CCV-SE-6	**GRAB**	--	SE Cresson	Uniax	**TBX-W**	CC Breccia (Altered White)	150.53	8,903	---	---	---	Intact	---	3.09E+06	0.27
CNI	2013	Core	2.49	5.00	2.01	13552-GT-13-1-0139	**GT-13-1**	139.9	WHEX	Triax	**XBS**	Pre-Cambrian Schist	178.63	21,724	1,000	1,897	11	Both	Intact	---	---
CNI	2013	Core	2.49	4.96	1.99	13552-GT-13-1-0262	**GT-13-1**	262.9	WHEX	Triax	**XBS**	Pre-Cambrian Schist	175.51	17,423	2,000	1,344	13	Fracture	Fracture	---	---
CNI	2013	Core	2.50	4.93	1.97	13552-GT-13-1-0303	**GT-13-1**	303.3	WHEX	Triax	**XBS**	Pre-Cambrian Schist	176.38	15,106	500	1,944	8	Fracture	Intact	---	---
CNI	2013	Core	2.50	4.96	1.99	13552-GT-13-1-0327	**GT-13-1**	327.0	WHEX	Triax	**XBS**	Pre-Cambrian Schist	177.00	22,072	1,000	1,486	15	Intact	Both	---	---
CNI	2013	Core	2.49	4.90	1.96	13552-GT-13-1-0423	**GT-13-1**	423.9	WHEX	Triax	**XBS**	Pre-Cambrian Schist	178.16	18,791	500	2,063	9	Both	Intact	---	---
CNI	2013	Core	2.48	4.92	1.99	13552-GT-13-1-0015	**GT-13-1**	15.1	WHEX	Uniax	**XBS**	Pre-Cambrian Schist	175.53	9,153	---	1,760	5	Intact	Intact	2.41E+06	0.15
CNI	2013	Core	2.50	4.89	1.96	13552-GT-13-1-0182	**GT-13-1**	183.0	WHEX	Uniax	**XBS**	Pre-Cambrian Schist	162.99	7,504	---	368	20	Both	Fracture	5.65E+06	0.20
CNI	2013	Core	2.49	4.88	1.96	13552-GT-13-1-0243	**GT-13-1**	243.8	WHEX	Uniax	**XBS**	Pre-Cambrian Schist	173.96	7,527	---	952	8	Fracture	Intact	2.49E+06	0.19
CNI	2015	Core	2.40	4.89	2.04	15700-GT11-4-0237	**GT-11-4**	237.1	Globe Hill Pipe	Triax	**GHP-TBX**	CCB Breccia from GHP	141.19	18,314	1,000	6,460	3	Fracture	Both	---	---
CNI	2015	Core	2.40	5.01	2.09	15700-GT11-4-0290-A	**GT-11-4**	290.2	Globe Hill Pipe	Triax	**GHP-TBX**	CCB Breccia from GHP	152.96	12,427	500	---	---	Fracture	---	---	---
CNI	2015	Core	2.39	4.94	2.06	15700-GT11-4-0290-B	**GT-11-4**	290.2	Globe Hill Pipe	Triax	**GHP-TBX**	CCB Breccia from GHP	153.96	17,935	1,000	---	---	Fracture	---	---	---
CNI	2015	Core	2.40	4.47	1.86	15700-GT11-4-0325	**GT-11-4**	325.2	Globe Hill Pipe	Triax	**GHP-TBX**	CCB Breccia from GHP	149.31	17,133	1,500	3,180	5	Fracture	Fracture	---	---

Table 4-2. Small Scale Direct Shear Testing Summary (1 of 2)

Updated SEP 2015		Sample Details							Rock Properties		Direct Shear Testing (σ/τ Space)							
Test Source (lab)	Test Year	Sample Type	Sample Size (in) diameter	Sample Number	Hole Number	Sample Depth (ft)	Field Location (mine)	Test Type	Site Lithologic Descriptors Abbrev	Site Lithologic Descriptors Lithology	Shear Type	#	Traces σ (psi)	Traces τ (psi)	Power K	Power M	Φ (deg)	Coh (psi)
CNI	2006	Core	2.747	949-0101-349	GT-01-01	349.0	???	SSDS	TBX	Cripple Creek Breccia	Joint / Mist	1	23.38	16.34	0.81	0.97	34.88	1.03
												2	46.19	34.42				
												3	92.28	65.96				
												4	139.57	98.04				
CNI	2006	Core	2.575	949-0101-358	GT-01-01	358.5	???	SSDS	TBX	Cripple Creek Breccia	Joint / Mist	1	23.49	23.39	1.41	0.88	37.00	6.14
												2	46.17	40.20				
												3	91.31	77.47				
												4	139.19	109.71				
CNI	2006	Core	2.416	949-196-291	GT-1-96	291.5	W Cresson	SSDS	TBX	Cripple Creek Breccia	Joint / Mist	1	24.74	22.21	0.96	0.94	34.72	3.83
												2	48.08	36.96				
												3	96.10	67.69				
												4	144.36	105.53				
CNI	2006	Core	2.825	949-196-304	GT-1-96	304.5	W Cresson	SSDS	TBX	Cripple Creek Breccia	Joint / Mist	1	24.16	14.69	0.77	0.97	33.04	0.70
												2	47.71	32.92				
												3	94.63	64.17				
												4	143.20	92.49				
CNI	2006	Core	2.017	949-981-1219	GT-98-1	1219.5	SE Cresson	SSDS	TBX	Cripple Creek Breccia	Joint / Mist	1	21.75	25.77	3.79	0.62	25.61	17.14
												2	42.94	39.04				
												3	86.15	60.31				
												4	128.42	77.30				
CNI	2009	Core	2.536	421-GT-09-02-332	GT-09-02	332.7	E Cresson	SSDS	TBX	Cripple Creek Breccia	Joint / Mist	1	22.88	15.73	0.90	0.91	29.11	3.64
												2	44.64	27.56				
												3	88.22	55.27				
												4	175.85	100.60				
CNI	2009	Core	2.454	421-GT-09-03-1069	GT-09-03	1069.6	E Cresson	SSDS	TBX	Cripple Creek Breccia	Joint / Mist	1	24.28	23.28	0.99	0.99	42.33	0.98
												2	46.91	42.83				
												3	92.48	86.21				
												4	184.89	169.09				
CNI	2006	Core	2.384	949-0101-393	GT-01-01	393.0	???	SSDS	TPH	Phonolite	Joint / Mist	1	22.91	14.72	0.52	1.01	28.22	0.68
												2	45.88	24.18				
												3	91.15	47.46				
												4	136.51	75.44				
CNI	2006	Core	2.377	949-0101-422	GT-01-01	422.0	???	SSDS	TPH	Phonolite	Joint / Mist	1	22.95	15.61	0.80	0.91	25.82	4.09
												2	46.84	28.60				
												3	94.01	44.81				
												4	141.22	74.90				
CNI	2006	Core	2.431	949-0101-432	GT-01-01	432.1	???	SSDS	TPH	Phonolite	Joint / Mist	1	22.34	18.00	0.70	0.99	33.73	1.15
												2	45.53	29.56				
												3	89.00	59.62				
												4	130.34	89.20				
CNI	2006	Core	2.703	949-0101-616_15	GT-01-01	616.3	???	SSDS	TPH	Phonolite	Joint / Mist	1	23.65	20.51	1.39	0.83	28.49	7.73
												2	45.88	34.01				
												3	91.34	54.77				
												4	138.08	83.92				
CNI	2006	Core	2.648	949-0101-616_16	GT-01-01	616.3	???	SSDS	TPH	Phonolite	Joint / Mist	1	23.06	25.65	1.83	0.81	32.34	10.30
												2	46.77	39.05				
												3	93.07	69.12				
												4	140.39	99.43				
CNI	2009	Core	2.661	421-GT-09-02-191	GT-09-02	191.8	E Cresson	SSDS	TPH	Phonolite	Joint / Mist	1	24.60	14.74	0.62	0.98	29.14	1.08
												2	47.76	28.65				
												3	95.80	53.19				
												4	192.00	108.55				
CNI	2009	Core	2.590	421-GT-09-02-215	GT-09-02	215.0	E Cresson	SSDS	TPH	Phonolite	Joint / Mist	1	22.48	16.00	1.35	0.80	24.12	7.86
												2	44.37	28.39				
												3	89.07	50.09				
												4	178.23	86.56				
CNI	2009	Surface	2.228	421-LMPBLK-1	--	9515	Cresson	SSDS	TLU	Lamprophyre	Joint / Mist	1	23.46	16.60	1.43	0.80	24.67	8.39
												2	45.33	30.29				
												3	91.10	53.08				
												4	179.78	89.55				
CNI	2009	Surface	2.226	421-LMPBLK-2	--	9515	Cresson	SSDS	TLU	Lamprophyre	Joint / Mist	1	23.63	17.39	1.46	0.78	22.96	8.96
												2	45.68	28.93				
												3	90.34	49.09				
												4	181.34	84.93				
CNI	2009	Surface	2.850	421-LMPBLK-3	--	9515	Cresson	SSDS	TLU	Lamprophyre	Joint / Mist	1	25.22	20.30	1.28	0.84	29.35	5.81
												2	50.71	32.17				
												3	97.52	60.79				
												4	48.87	32.82				
												5	193.24	103.49				
CNI	2009	Surface	2.728	421-LMPBLK-4	--	9515	Cresson	SSDS	TLU	Lamprophyre	Joint / Mist	1	24.90	19.00	1.44	0.82	27.22	8.63
												2	48.42	33.80				
												3	94.96	61.35				
												4	189.29	104.32				
CNI	2009	Surface	2.490	421-CCV-FLT-1	--	10250	Cresson	SSDS	FLT	Fault Gouge	Remold	1	10.95	10.35	1.01	0.92	33.02	4.01
												2	28.73	21.45				
												3	57.03	42.41				
												4	114.23	79.88				
												5	231.78	153.73				
CNI	2009	Core	2.990	421-GT-09-03-890	GT-09-03	890.0	E Cresson	SSDS	FLT	Fault Gouge	Remold	1	22.47	16.34	0.74	0.99	35.19	0.49
												2	44.98	31.99				
												3	91.70	65.47				
												4	181.29	128.23				

Table 4-2. Small Scale Direct Shear Testing Summary (2 of 2)

Updated SEP 2015		Sample Details							Rock Properties		Direct Shear Testing (σ/τ Space)							
Test Source (lab)	Test Year	Sample Type	Sample Size (in) diameter	Sample Number	Hole Number	Sample Depth (ft)	Field Location (mine)	Test Type	Site Lithologic Descriptors Abbrev	Lithology	Shear Type	#	Traces σ (psi)	Traces τ (psi)	Power K	Power M	Φ (deg)	Coh (psi)
CNI	2010	Core	2.499	455-GT10-5-102-216	GT10-5-102	216.0	???	SSDS	rub	Rubble	Remold	1	35.19	33.67	1.64	0.87	36.58	12.45
												2	59.11	61.18				
												3	172.83	141.86				
												4	288.58	225.58				
CNI	2010	Core	2.510	455-GT10-5-321	GT10-5	321.0	N WHEX	SSDS	rub	Rubble	Remold	1	30.20	34.85	1.55	0.89	37.74	10.97
												2	58.66	53.41				
												3	168.71	146.00				
												4	298.25	239.84				
CNI	2010	Core	2.490	455-GT10-5-0442	GT10-5	442.9	N WHEX	SSDS	rub	Rubble	Remold	1	29.01	27.35	1.19	0.92	35.90	7.23
												2	57.41	49.69				
												3	175.50	134.41				
												4	294.81	220.43				
CNI	2013	Core	2.672	13552-GT-13-1-0131	GT-13-1	131.1	WHEX	SSDS	XBS	Pre-Cambrian Schist	Joint / Mist	1	22.31	11.99	0.86	0.84	19.33	4.97
												2	44.53	21.12				
												3	87.76	36.36				
												4	176.37	66.51				
CNI	2013	Core	2.634	13552-GT-13-1-0143	GT-13-1	143.7	WHEX	SSDS	XBS	Pre-Cambrian Schist	Joint / Mist	1	22.52	13.71	0.87	0.84	19.84	5.23
												2	43.98	20.50				
												3	87.37	37.00				
												4	174.35	68.10				
CNI	2013	Core	2.734	13552-GT-13-1-0368	GT-13-1	368.9	WHEX	SSDS	XBS	Pre-Cambrian Schist	Joint / Mist	1	20.70	11.91	0.80	0.86	20.14	4.50
												2	41.97	20.68				
												3	83.76	34.35				
												4	168.44	66.52				
CNI	2013	Core	2.145	13552-GT-13-1-0377	GT-13-1	377.0	WHEX	SSDS	XBS	Pre-Cambrian Schist	Joint / Mist	1	23.43	10.43	0.57	0.93	20.97	2.13
												2	45.66	19.99				
												3	88.03	36.54				
												4	175.09	68.91				
CNI	2015	Core	2.490	15700-CCV-GT11-4-0685	GT11-4	685.0	Globe Hill Pipe	SSDS	GHP-TBX	CCB Breccia from GHP	Remold	1	23.29	16.19	0.79	0.96	32.77	2.01
												2	48.18	34.24				
												3	95.40	63.01				
												4	199.62	130.49				

Table 4-3. Intact Rock Properties

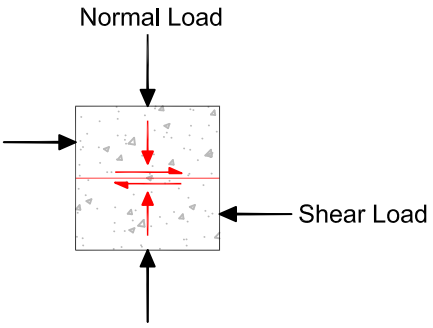
Rock Type	Rock Code	GTRCK	Density (pcf)	Elastic		Compressive	Triaxial		Tensile
				Young's Modulus (psi)	Poisson's Ratio	Uniaxial Comp. (psi)	Cohesion (psi)	Friction Angle (deg)	Disk Tension (psi)
Cripple Creek Breccia	TBX (42)	1	150	3.94E+06	0.18	9928	2344	43.5	1279
Phonolite	TPH (21)	2	153	5.37E+06	0.24	8849	2114	44.7	1761
Lamprophyre	TLU (6)	3	173	4.35E+06	0.19	8731	1960	36.1	1061
Pre-Cambrian Schist	XBS (72)	4	176	3.52E+06	0.18	8061	2207	46.3	1477

Table 4-4. Fracture Shear Strengths

Rock Type	Rock Code	GTRCK	Linear				Power	
			Phi (deg)	S.D. Phi	Cohesion (psi)	S.D. Cohesion	K (for X in psi)	M
Cripple Creek Breccia	TBX (42)	1	34.1	2.7	4.8	1.3	1.15	0.90
Phonolite	TPH (21)	2	28.9	1.7	4.7	1.9	0.95	0.90
Lamprophyre	TLU (6)	3	26.1	1.8	8.0	0.9	1.40	0.81
Pre-Cambrian Schist	XBS (72)	4	20.1	0.1	4.2	0.8	0.77	0.87
Rubble/Colluvium	--	5	36.8	0.8	10.2	3.3	1.46	0.89
Fault Gouge	FLT (4)	--	34.1	1.2	2.3	0.1	0.86	0.96

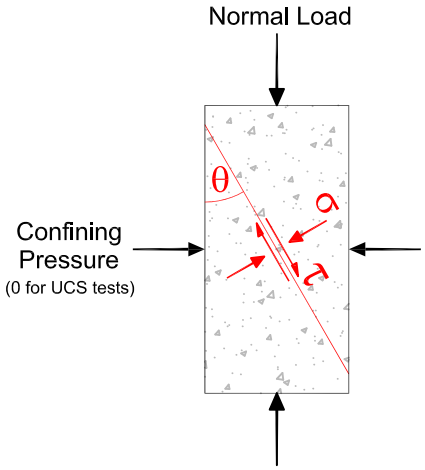
Table 4-5. Rock Mass Properties (Isotropic)

Rock Type	Rock Code	GTRCK	RQD (%)	m_i	Density (pcf)	Elastic		Tensile Strength (psi)	Mean Strengths	
						Young's Modulus (psi)	Poisson's Ratio		Cohesion (psi)	Friction Angle (deg)
Cripple Creek Breccia	TBX (42)	1	90	13.9	150	1.36E+06	0.27	80	432	39.6°
			80	13.9	150	1.14E+06	0.28	56	333	38.9°
			70	13.9	150	9.24E+05	0.28	31	258	38.2°
			60	13.9	150	7.48E+05	0.28	22	199	37.7°
			50	13.9	150	5.71E+05	0.28	13	154	37.2°
			40	13.9	150	4.51E+05	0.29	10	119	36.8°
			30	13.9	150	3.31E+05	0.29	6	92	36.4°
			20	13.9	150	2.70E+05	0.29	5	71	36.1°
			10	13.9	150	2.09E+05	0.29	3	55	35.8°
Phonolite	TPH (21)	2	90	16.2	153	8.78E+05	0.21	10	390	38.4°
			80	16.2	153	6.80E+05	0.23	7	301	37.2°
			70	16.2	153	4.82E+05	0.24	4	232	36.1°
			60	16.2	153	3.85E+05	0.25	3	180	35.2°
			50	16.2	153	2.87E+05	0.26	2	139	34.4°
			40	16.2	153	2.51E+05	0.27	2	107	33.6°
			30	16.2	153	2.14E+05	0.28	1	83	33.0°
			20	16.2	153	1.95E+05	0.28	1	65	32.5°
			10	16.2	153	1.76E+05	0.30	1	50	32.0°
Lamprophyre	TLU (6)	3	90	7.1	173	4.69E+05	0.32	23	362	31.9°
			80	7.1	173	3.72E+05	0.33	17	280	31.1°
			70	7.1	173	2.74E+05	0.33	10	216	30.4°
			60	7.1	173	2.28E+05	0.34	8	167	29.8°
			50	7.1	173	1.82E+05	0.34	5	130	29.3°
			40	7.1	173	1.63E+05	0.34	4	101	28.9°
			30	7.1	173	1.43E+05	0.34	3	78	28.5°
			20	7.1	173	1.32E+05	0.35	2	61	28.2°
			10	7.1	173	1.20E+05	0.35	1	48	27.9°
Pre-Cambrian Schist	XBS (72)	4	90	21	176	3.53E+05	0.29	8	407	36.5°
			80	21	176	2.73E+05	0.30	5	314	34.5°
			70	21	176	1.93E+05	0.31	3	242	32.7°
			60	21	176	1.59E+05	0.33	2	187	31.2°
			50	21	176	1.26E+05	0.34	1	145	29.7°
			40	21	176	1.12E+05	0.35	1	112	28.5°
			30	21	176	9.74E+04	0.35	1	87	27.4°
			20	21	176	9.16E+04	0.36	1	67	26.4°
			10	21	176	8.58E+04	0.36	1	52	25.6°
Globe Hill Pipe	--	5	--	--	150	The Globe Hill Pipe Shear Strength is Modeled with a Power Curve Defined by $\tau=K*\sigma_n^m$, where K=1.707 (for σ_n in psi) and m=0.846				
Colluvium / Weathered	--	6	--	--	120	--	--	1	14	37°
Mine Backfill	--	7	--	--	120	--	--	1	5	37°



Small-Scale
Direct-Shear

Figure 4-1a

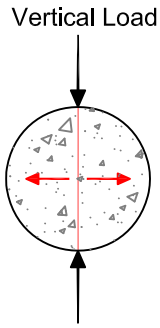


Unconfined
Compression

and

Triaxial
Compression

Figure 4-1b



Brazilian
Disc Tension

Figure 4-1c

LEGEND

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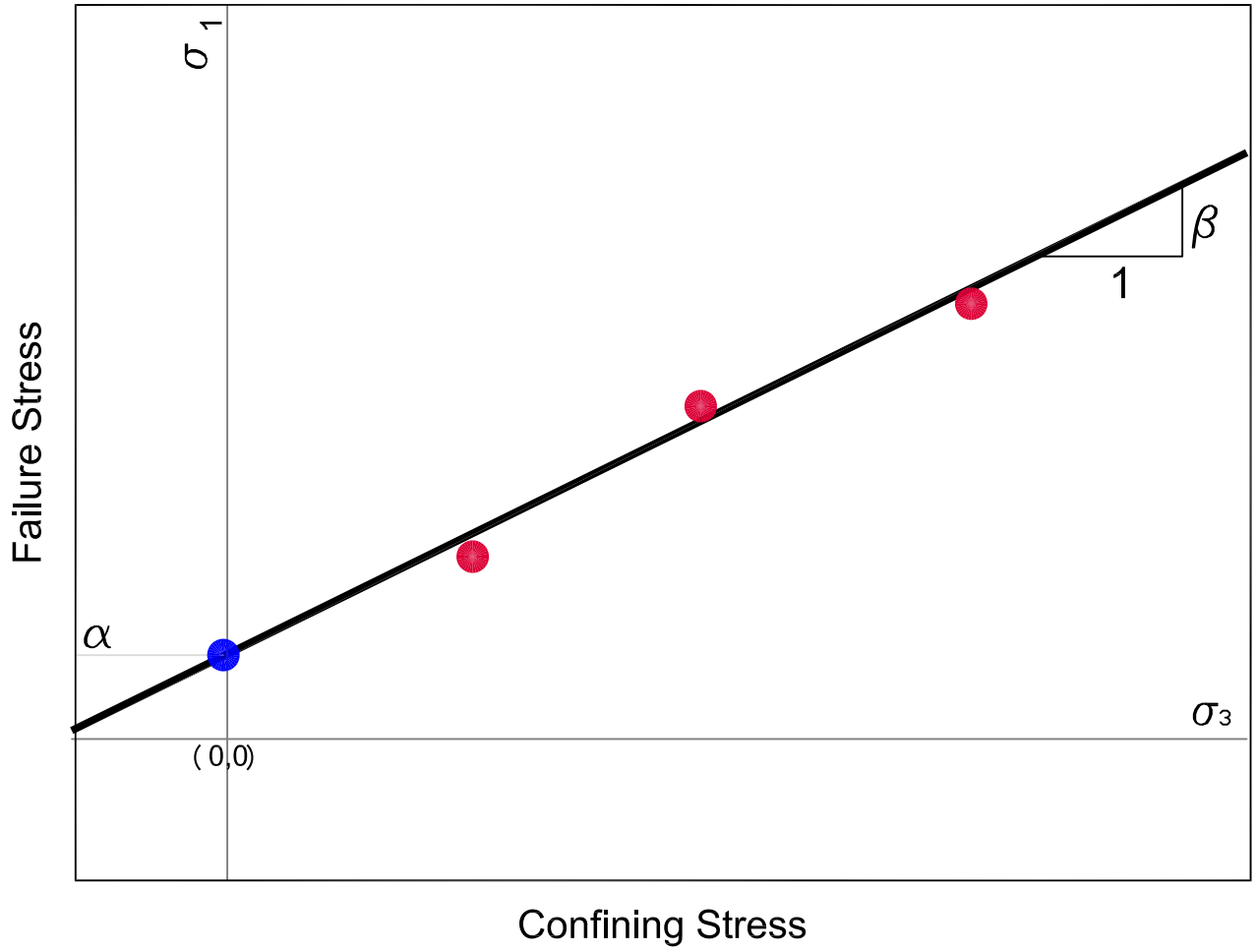
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\2015\NAU_STUDY\REPORT\ROCK STRENGTH PARAMETERS\FIGURES\FIG-4-01.DWG

LABORATORY TESTING
TYPES OF TESTS
ON CORE

CRIPPLE CREEK & VICTOR

SCALE N.T.S. | FIGURE 4-1



● = Triaxial ● = Uniaxial

$\sigma_1 = \alpha + \sigma_3\beta$ β = Slope of Linear "Best Fit" α = Intercept of Linear "Best Fit"

$\mu = (\beta - 1) / (2\sqrt{\beta})$ $c = \alpha / (2\sqrt{\beta})$

In terms of normal stress (σ_n) and shear stress (τ) , the strength of the intact rock is defined as:

$$\tau = c + \mu\sigma_n$$

c = Cohesion $\mu = \tan\varphi$

φ = Friction Angle

LEGEND

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TUCSON, ARIZONA USA

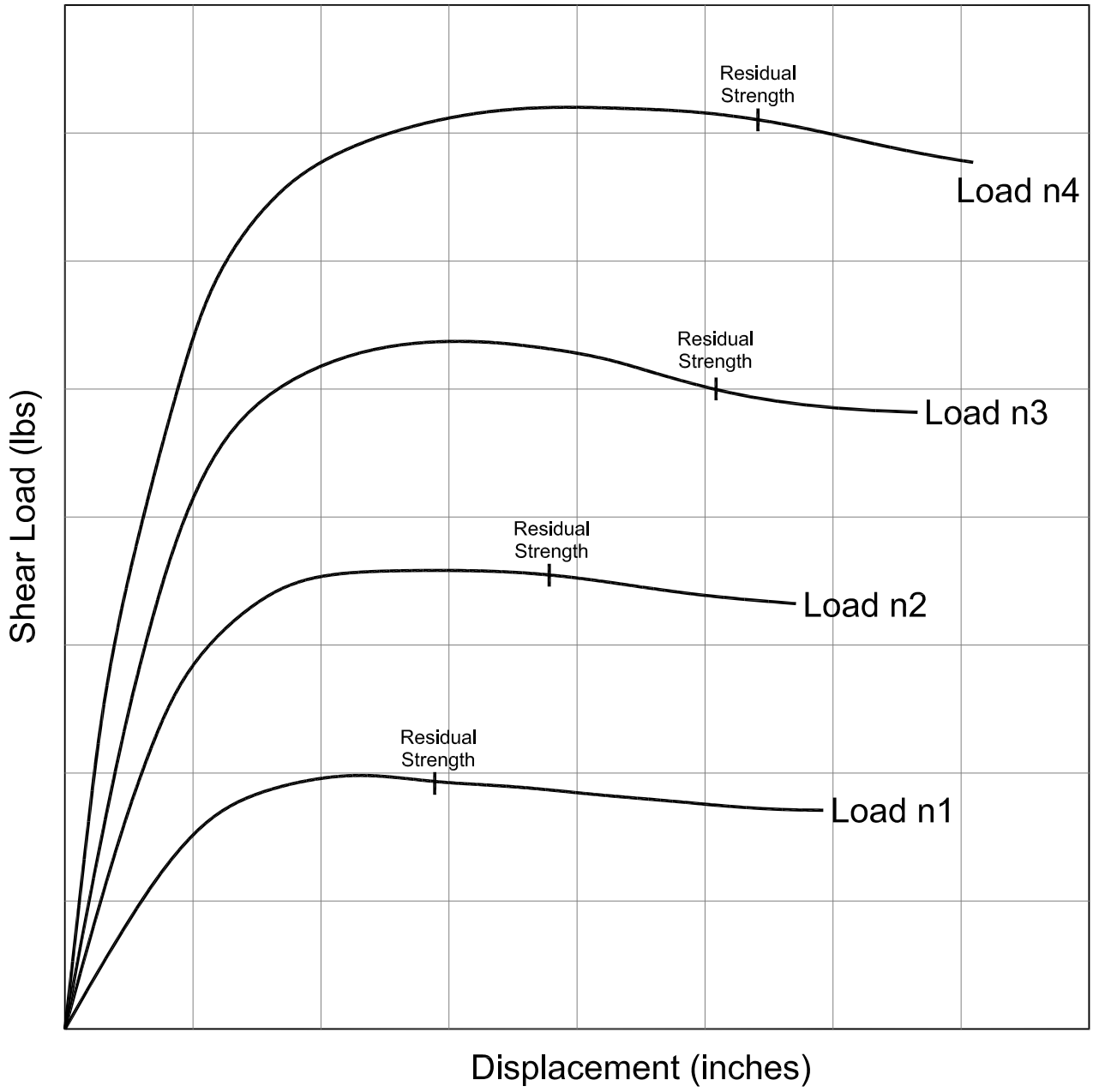
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\2015\NAU_STUDY\REPORT\ROCK STRENGTH PARAMETERS\FIGURES\FIG-4-02.DWG

LABORATORY TESTING COMPRESSION DATA REDUCTION

CRIPPLE CREEK & VICTOR

SCALE N.T.S. FIGURE 4-2



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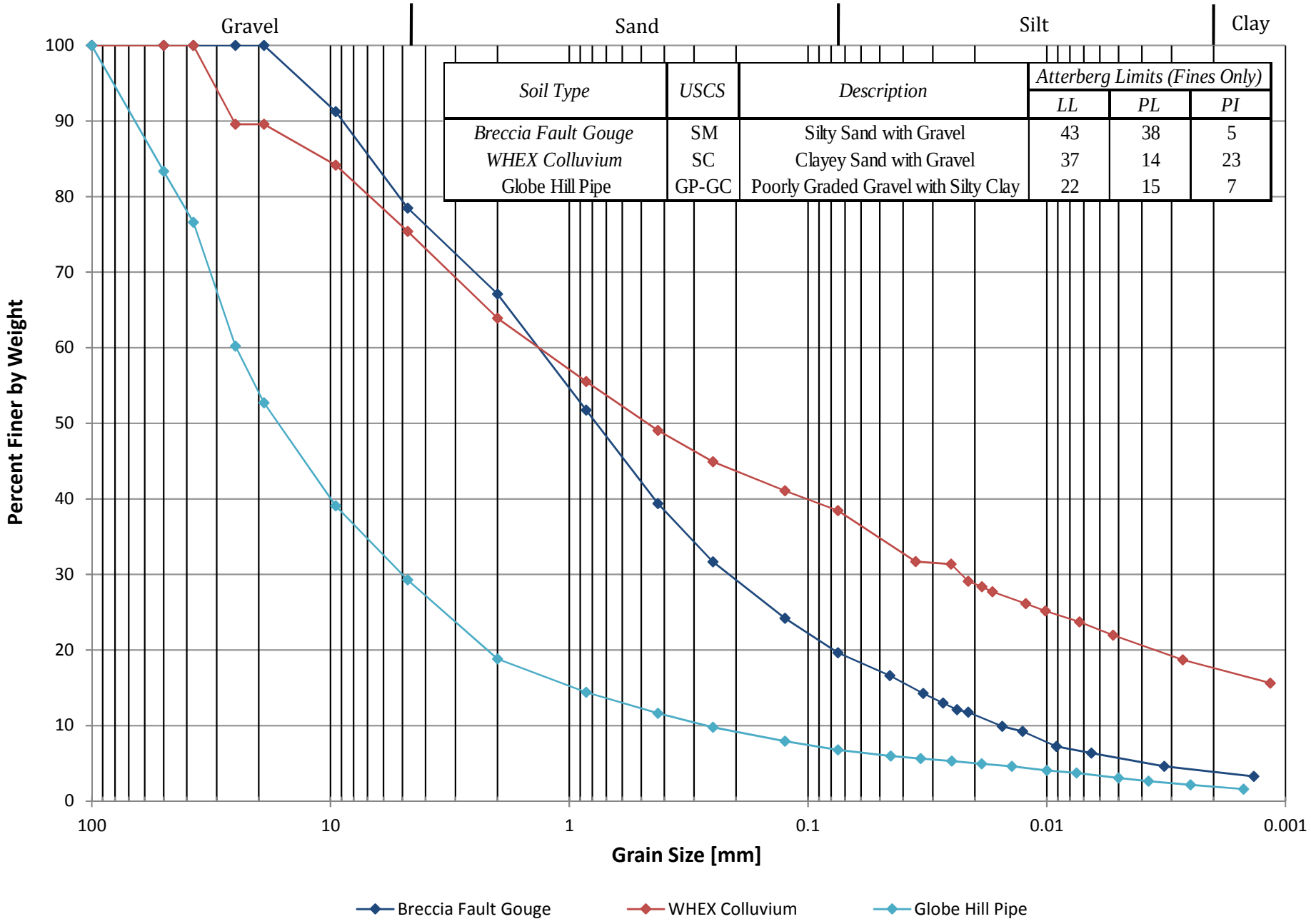
\2015\NAU_STUDY\REPORT\ROCK STRENGTH PARAMETERS\FIGURES\FIG-4-03.DWG

LABORATORY TESTING DIRECT-SHEAR TEST GRAPH

CRIPPLE CREEK & VICTOR

SCALE N.T.S.

FIGURE 4-3



Soil Type	*USCS*	*Description*	*Atterberg Limits (Fines Only)*		
			LL	*PL*	*PI*
Breccia Fault Gouge	SM	Silty Sand with Gravel	43	38	5
WHEX Colluvium	SC	Clayey Sand with Gravel	37	14	23
Globe Hill Pipe	GP-GC	Poorly Graded Gravel with Silty Clay	22	15	7

Figure 4-3. Summary of Soil Classification Testing Results

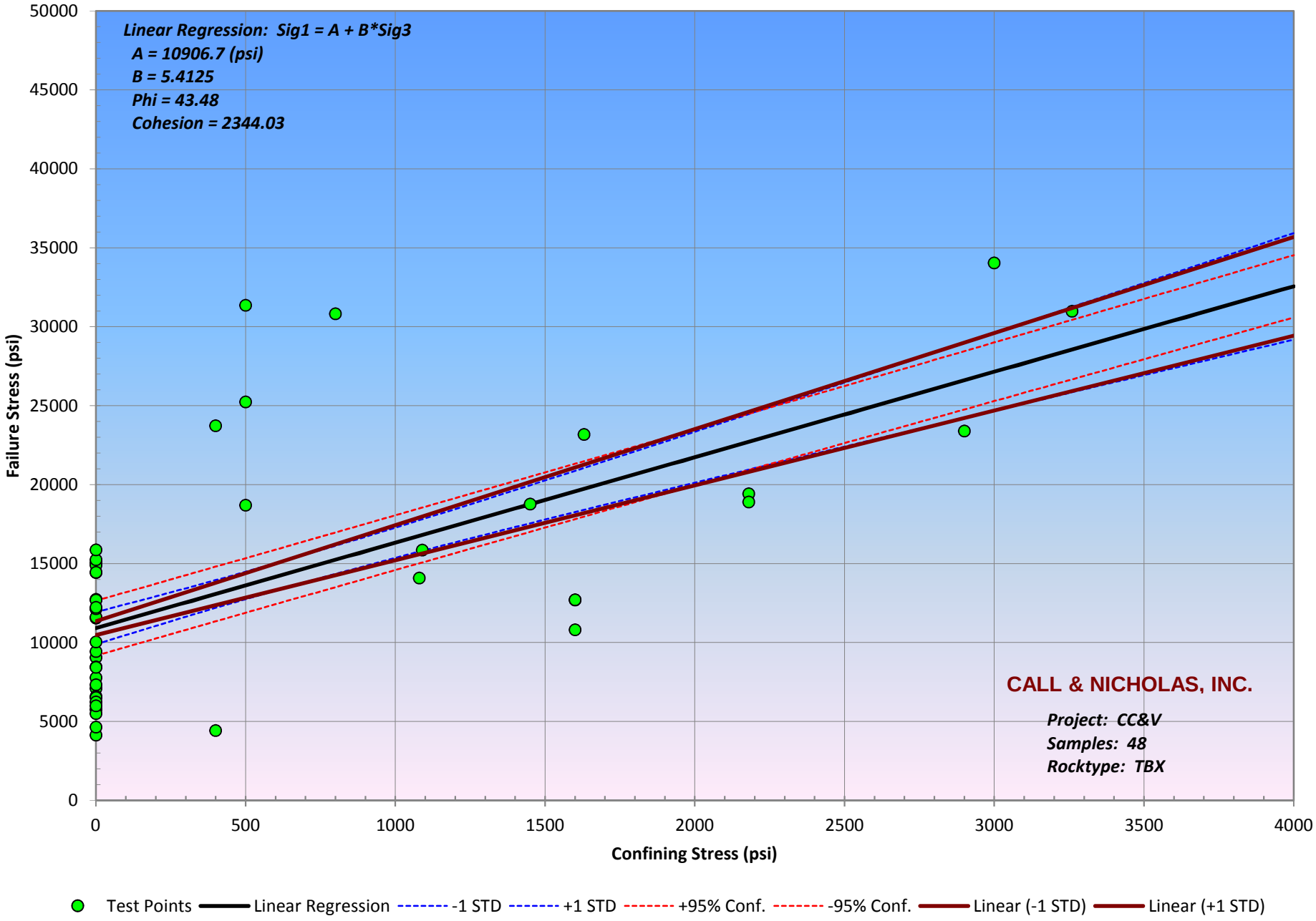


Figure 4-5. Linear Intact Testing Regression, Cripple Creek Breccia

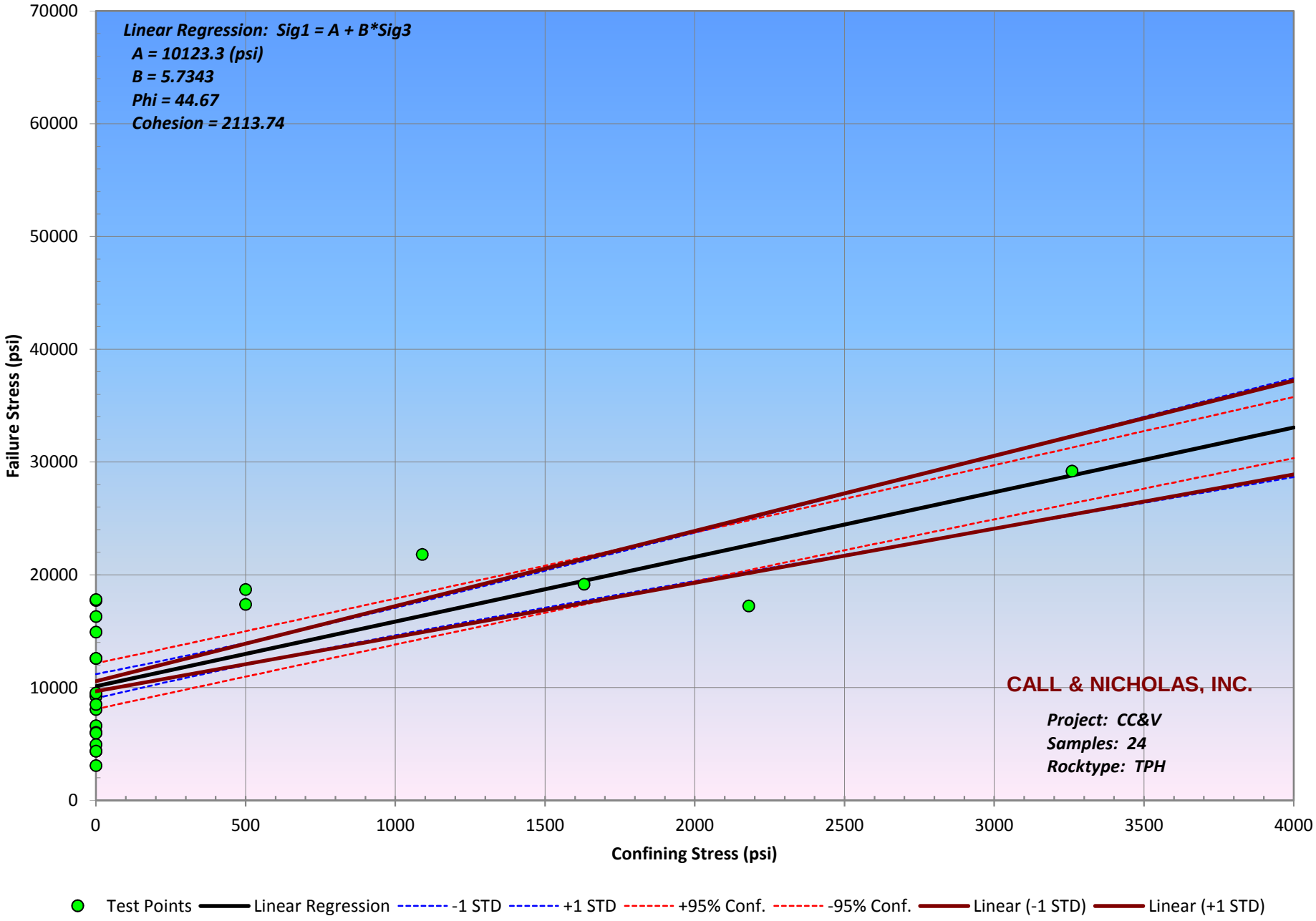


Figure 4-6. Linear Intact Testing Regression, Phonolite

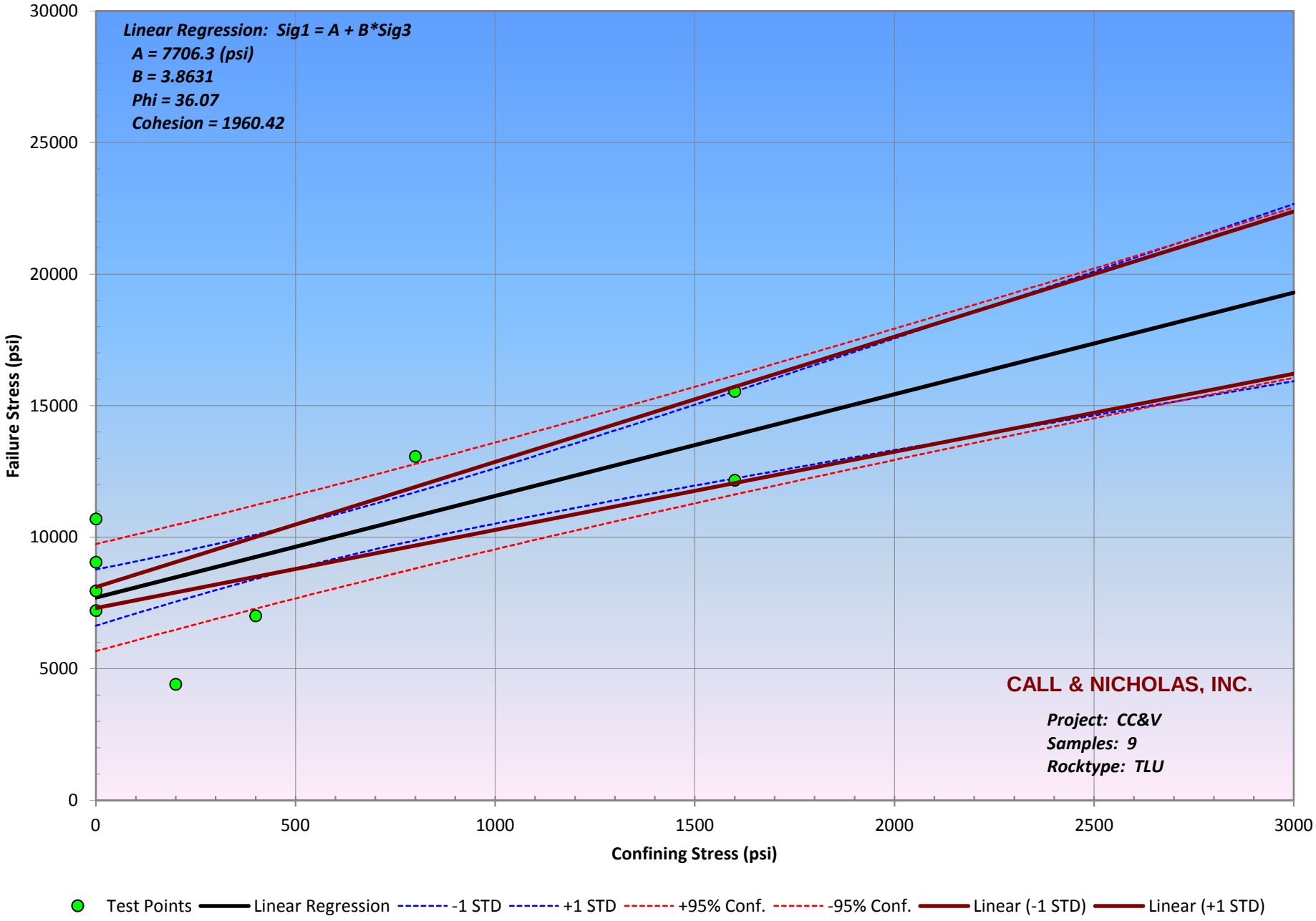


Figure 4-7. Linear Intact Testing Regression, Lamprophyre

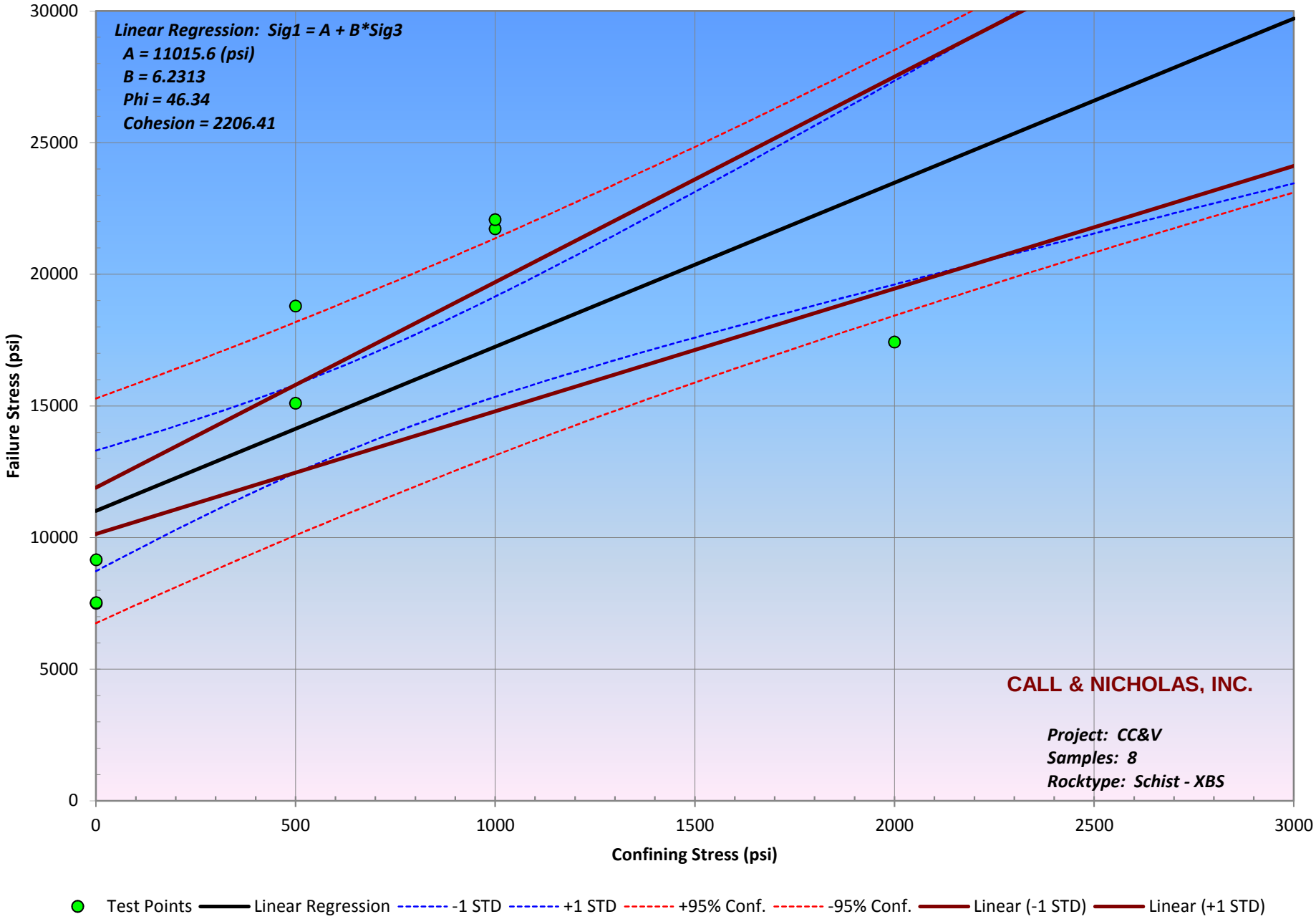


Figure 4-8. Linear Intact Testing Regression, Precambrian Schist

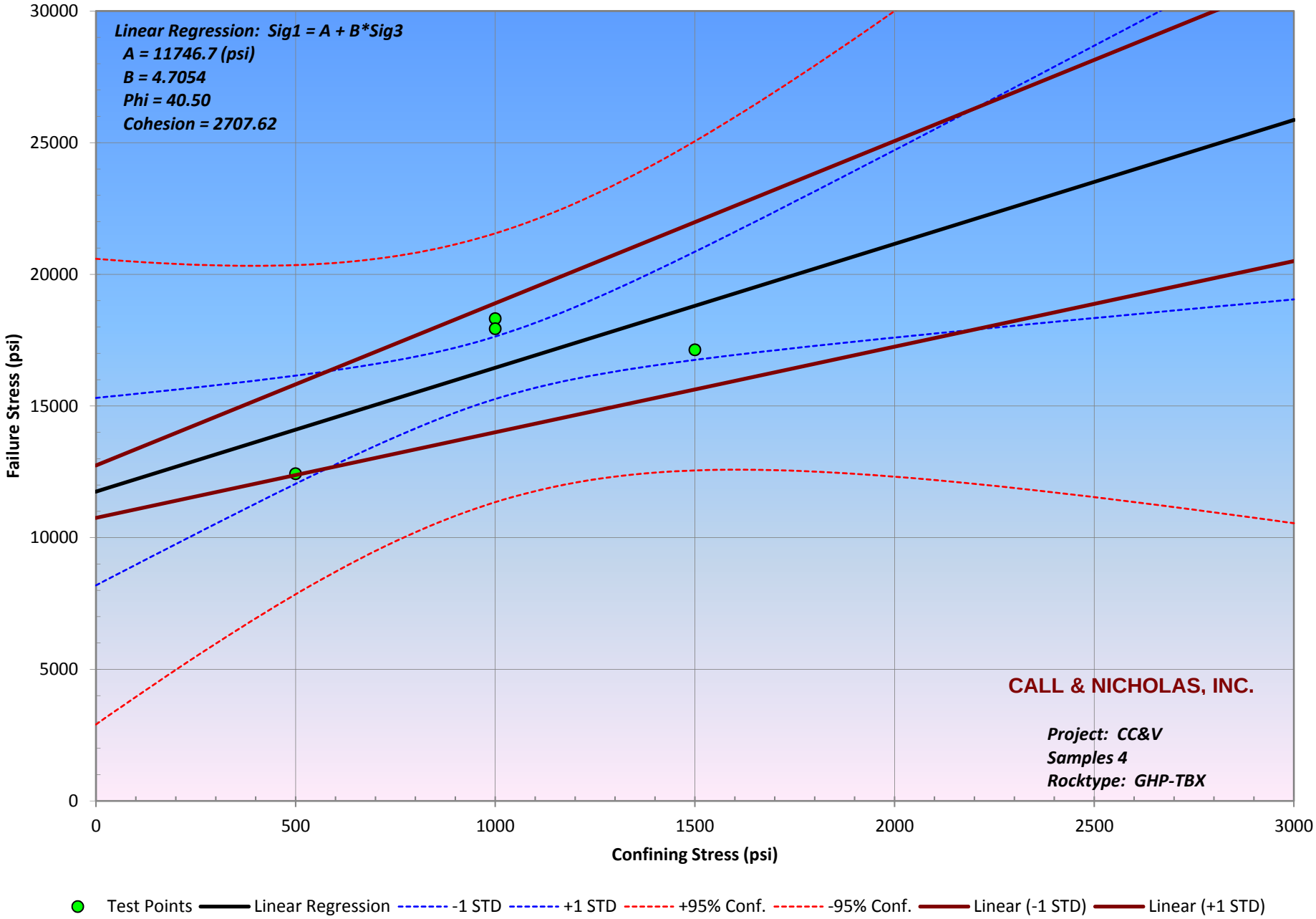


Figure 4-9. Linear Intact Testing Regression, Globe Hill Pipe (Cripple Creek Breccia)

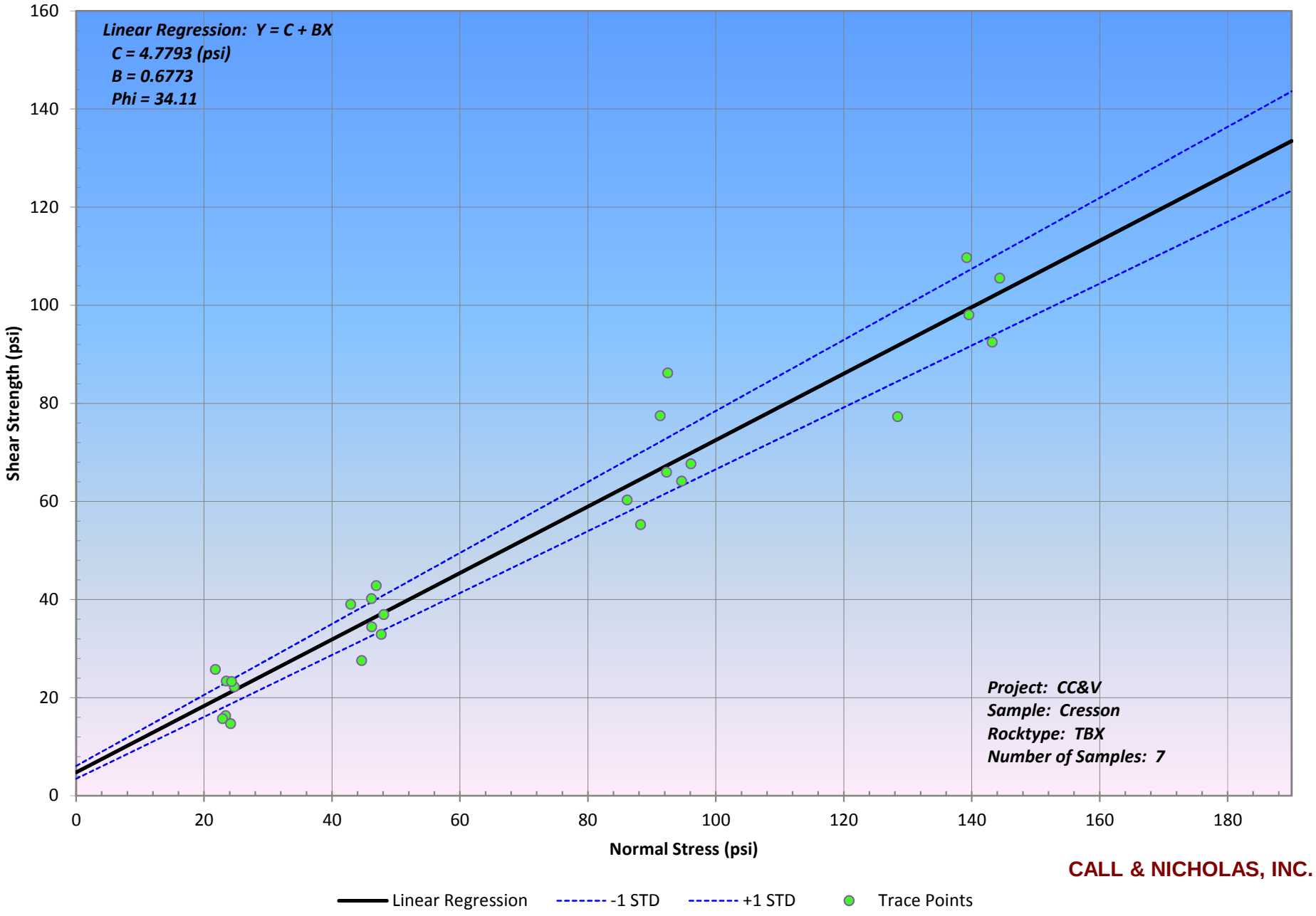


Figure 4-10. Small Scale Direct Shear Testing Linear Regression, Cripple Creek Breccia

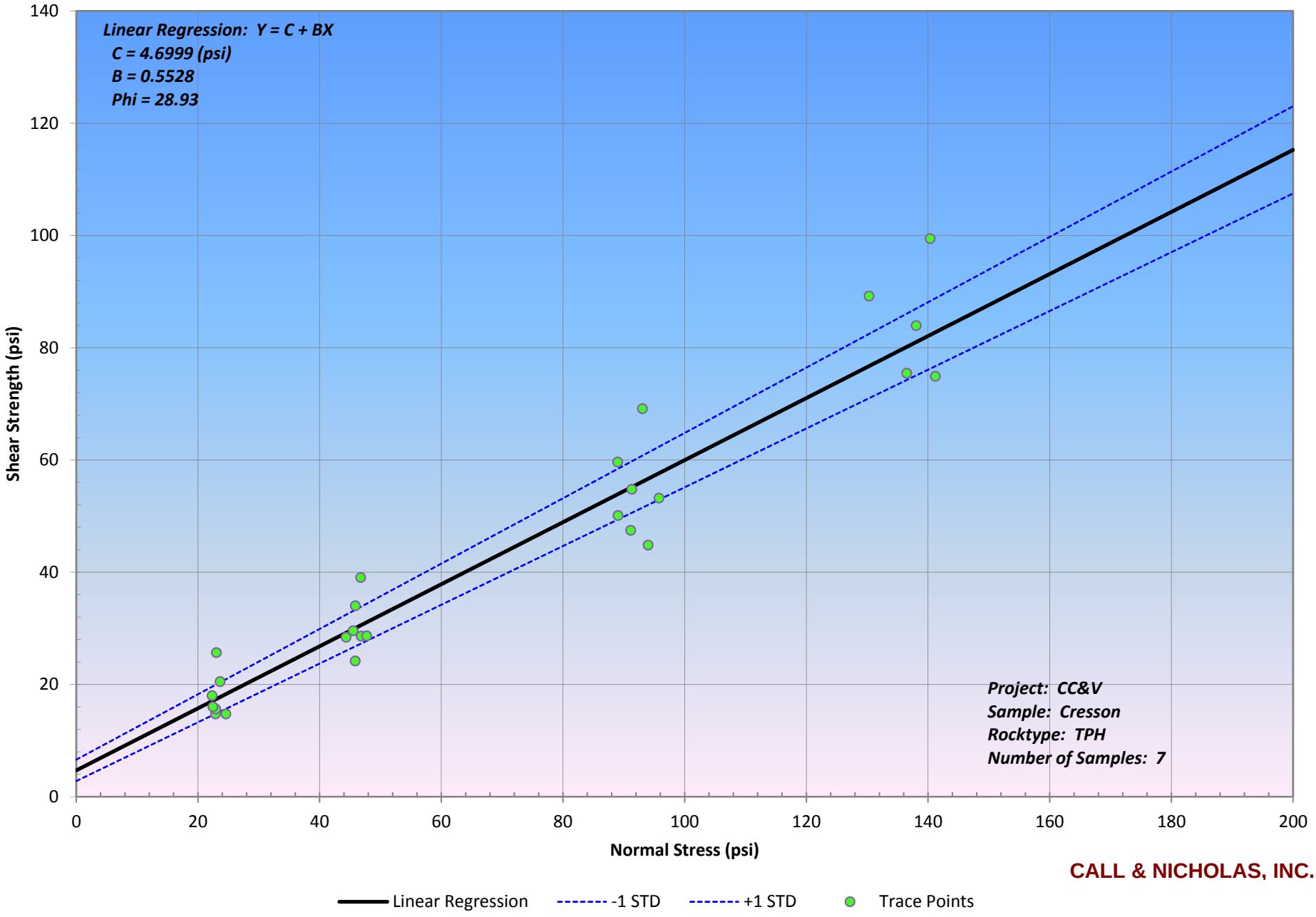


Figure 4-11. Small Scale Direct Shear Testing Linear Regression, Phonolite

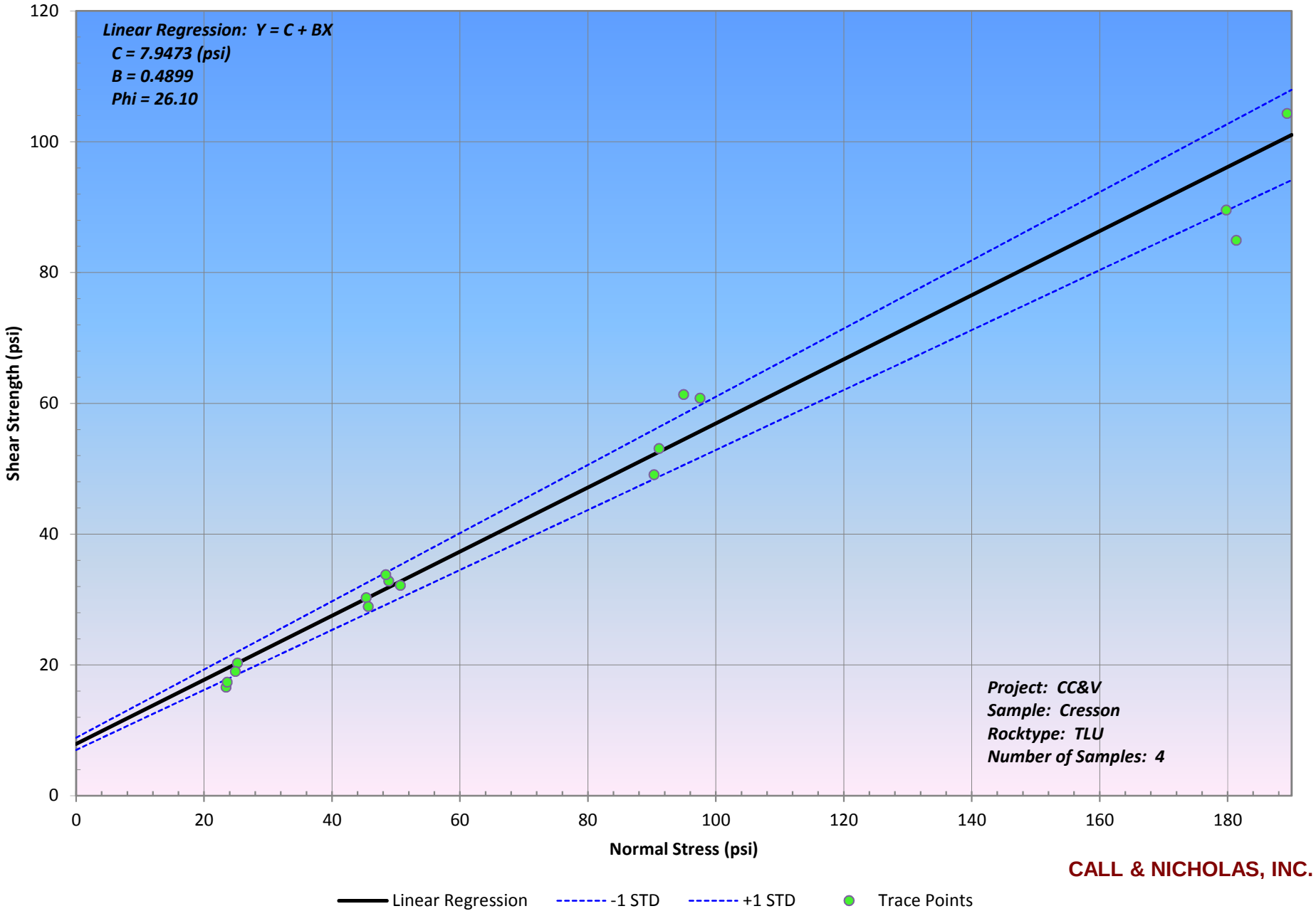


Figure 4-12. Small Scale Direct Shear Testing Linear Regression, Lamprophyre

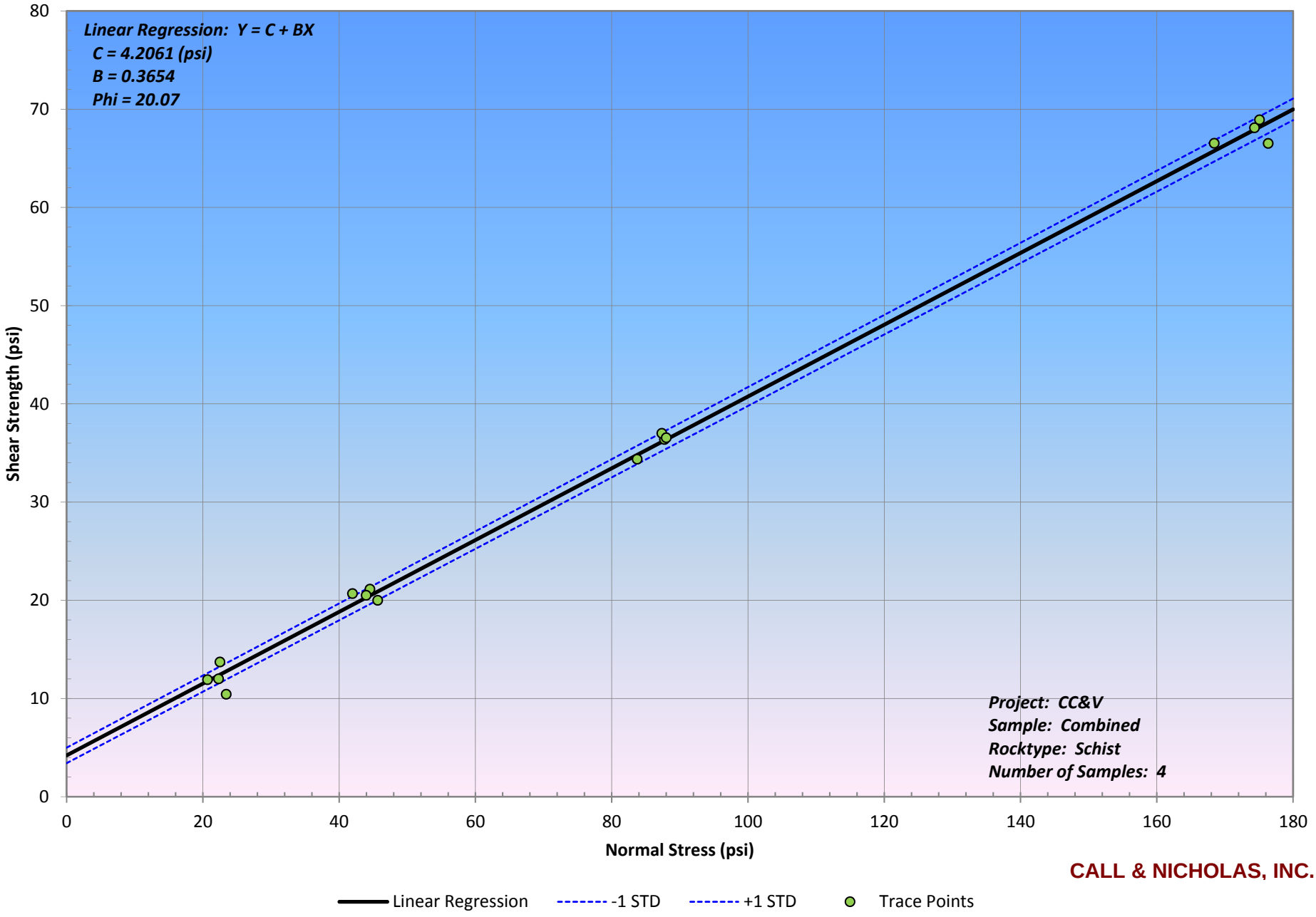


Figure 4-13. Small Scale Direct Shear Testing Linear Regression, Precambrian Schist

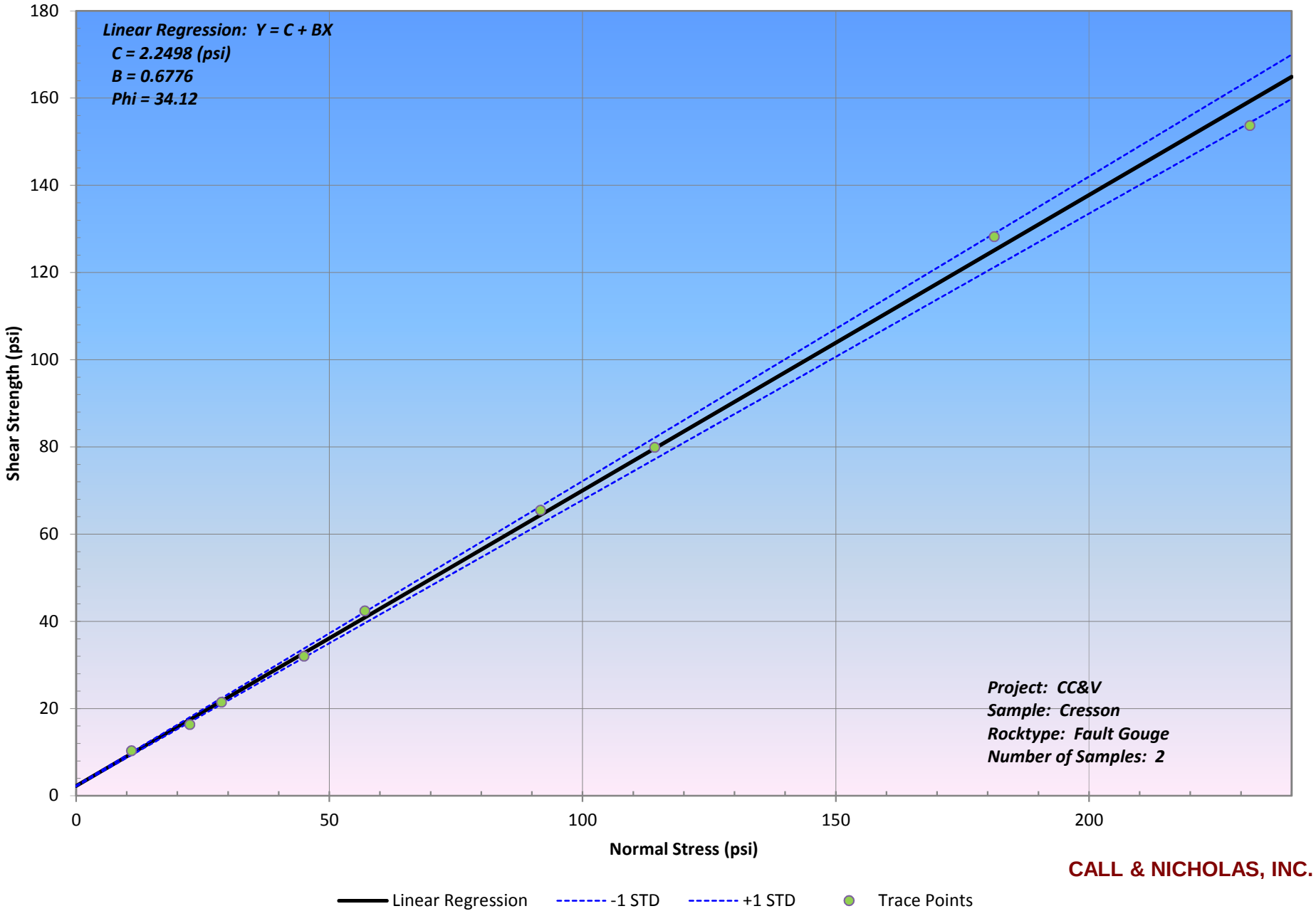


Figure 4-14. Small Scale Direct Shear Testing Linear Regression, Fault Gouge

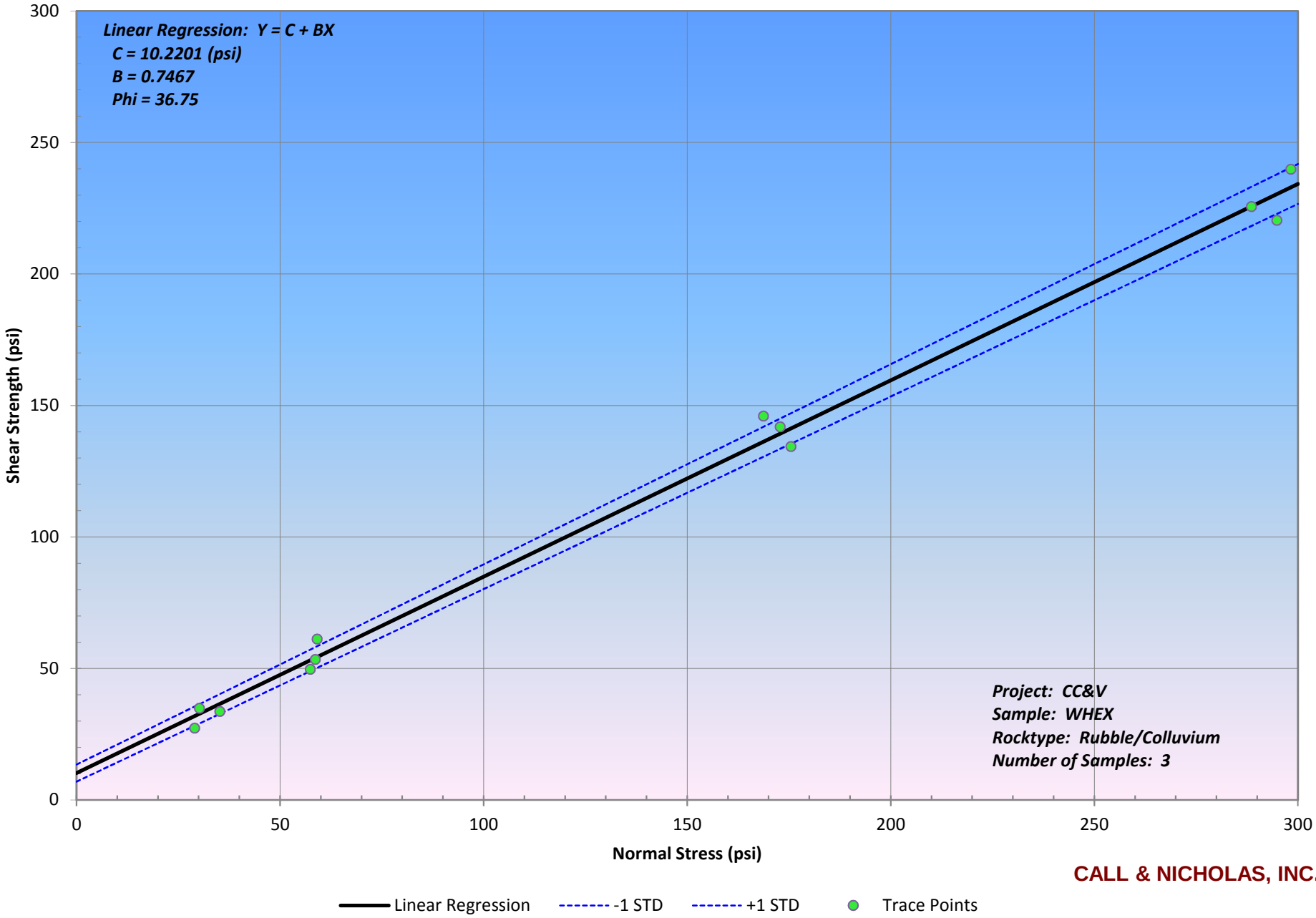


Figure 4-15. Small Scale Direct Shear Testing Linear Regression, WHEX Rubble/Colluvium

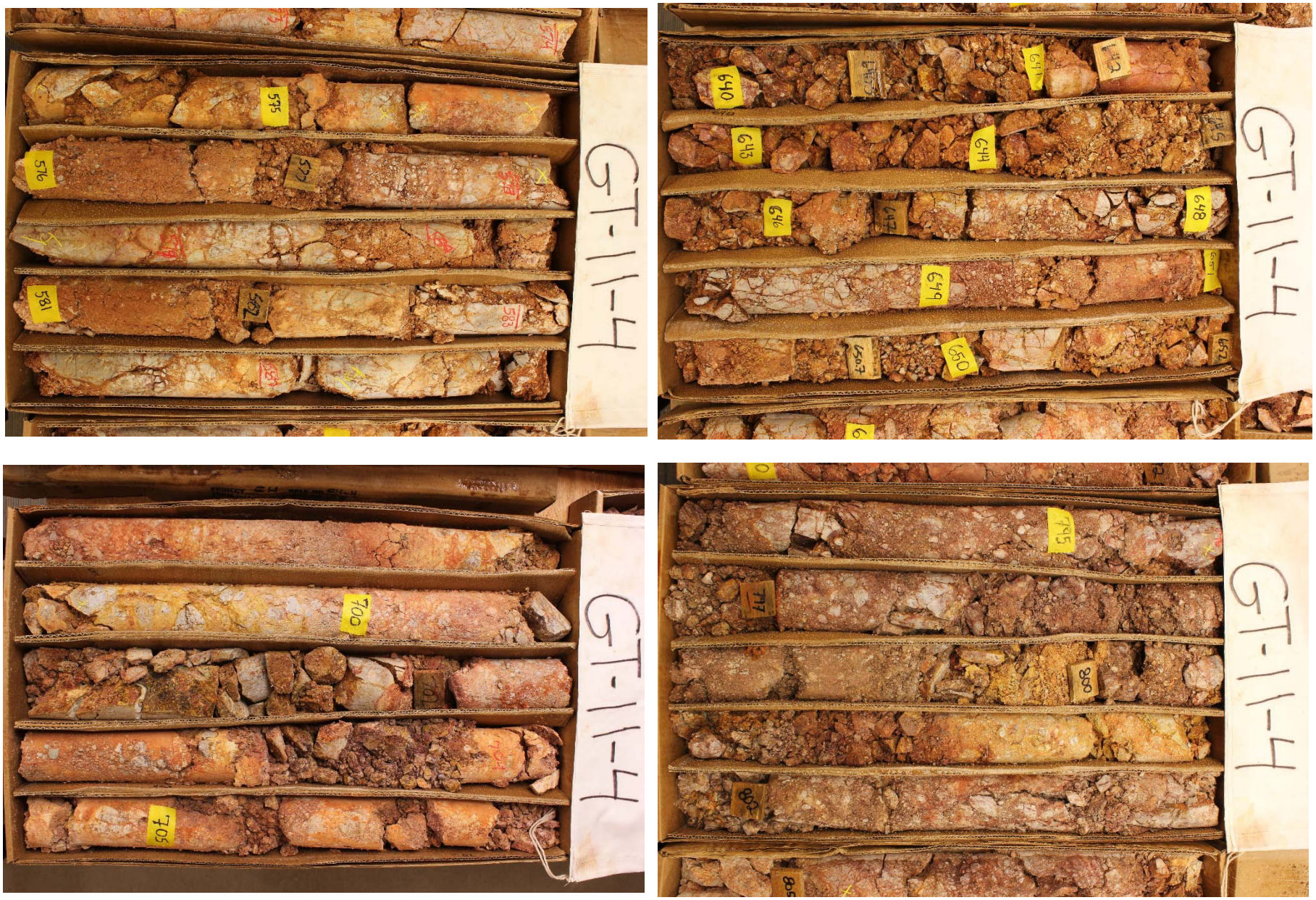
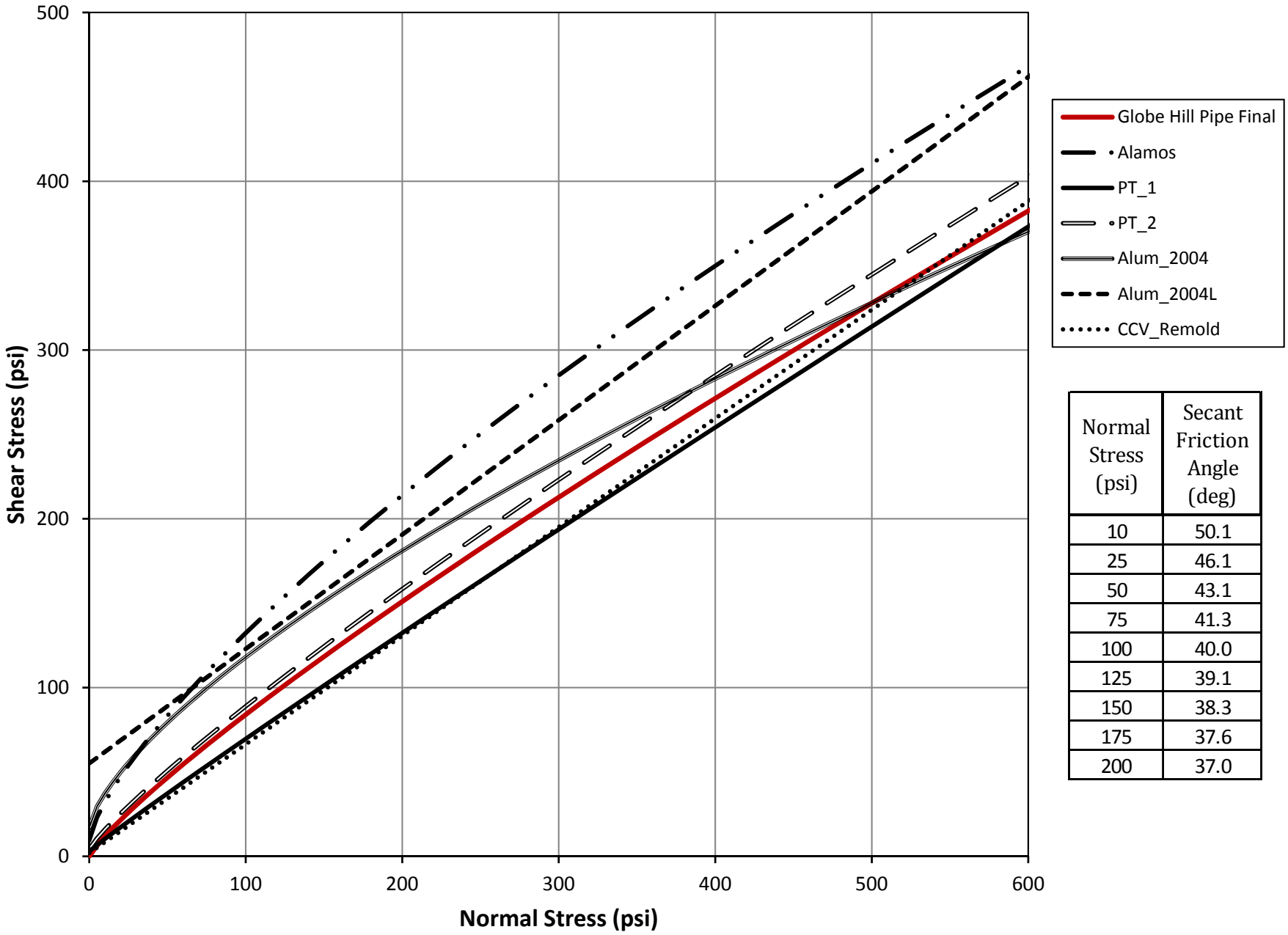
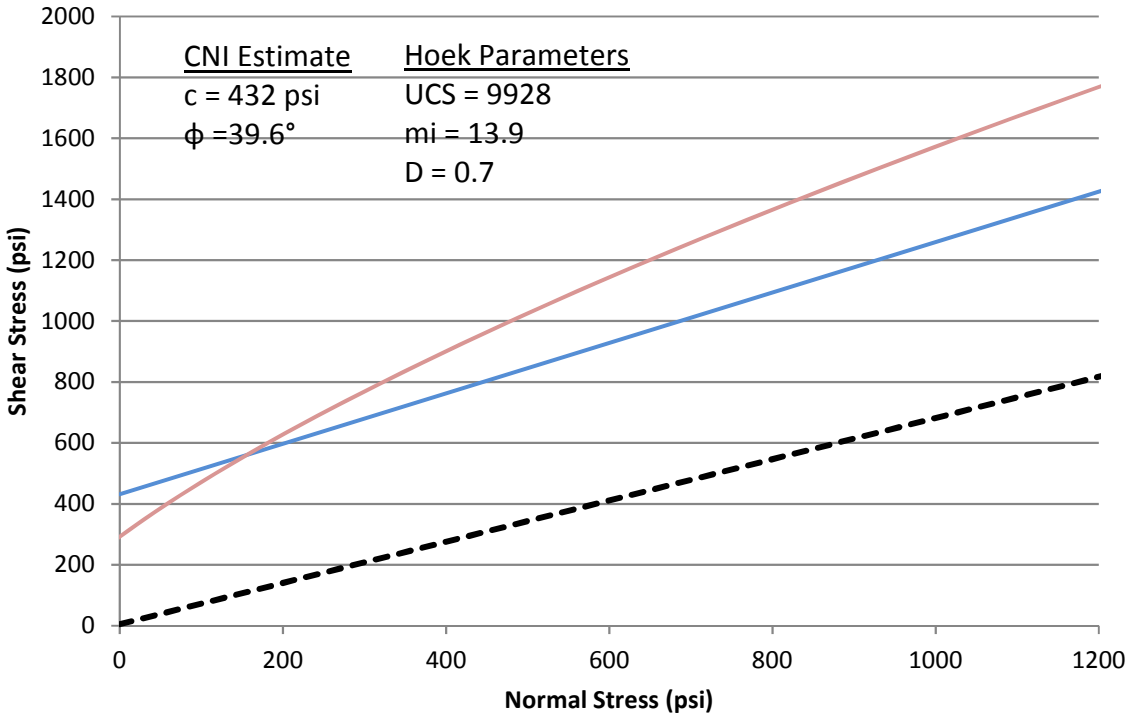


Figure 4-16. Photos of Core from Hole GT11-04 that are Typical of the Globe Hill Pipe Zone

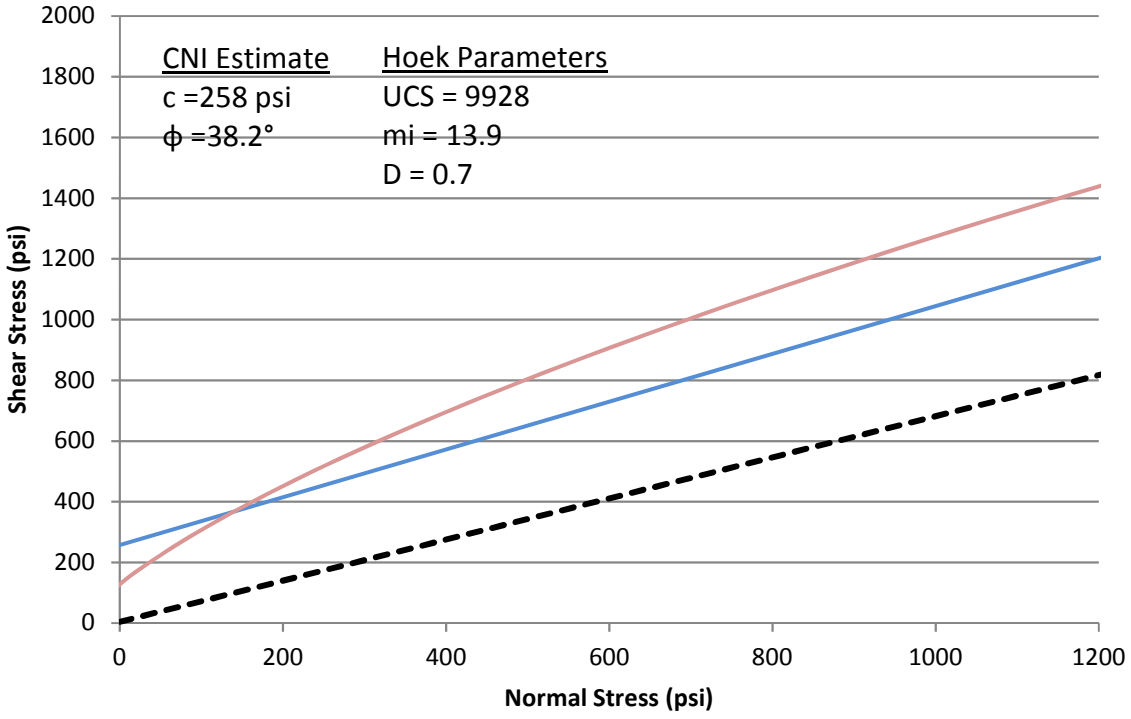


Normal Stress (psi)	Secant Friction Angle (deg)
10	50.1
25	46.1
50	43.1
75	41.3
100	40.0
125	39.1
150	38.3
175	37.6
200	37.0

Figure 4-17. Modeled Globe Hill Pipe Shear Strength and Shear Strengths Utilized for Similar Type Materials at Other Mines



Rock-mass Strength Estimation, Cripple Creek Breccia (TBX), 90% RQD



Rock-mass Strength Estimation, Cripple Creek Breccia (TBX), 70% RQD

CNI Method Rmass Estimate
Hoek-Brown Rmass Estimate (D=0.7)
Fracture Shear Strength

Figure 4-18. Rock Mass Strength Estimation, TBX 90% and 70% RQD

5.0 BENCH-SCALE ANALYSIS

5.1 Bench-Scale Analysis Methodology

5.1.1 Introduction to Backbreak

CNI uses a probabilistic numerical analysis program called Backbreak to determine the expected bench-face angle (BFA) distribution for each distinct pit wall orientation. This distribution is directly related to the amount of back break calculated from structure length, structure spacing, structure orientation, and joint shear strength. Back break is defined as the distance behind the crest that a vertical bench sloughs into the pit along daylighted geologic structures (Figure 5-1).

Due to the inherent variability of the geologic input parameters, probabilistic methods must be used in bench-scale analysis. The probability of instability for a specific geologic structure has three parts: (1) probability that a structure with an adverse orientation exists, (2) probability that the structure is long enough to daylight, and (3) the probability of sliding along the structure. The probability of instability for a particular geologic structure is the product of these three separate probabilities, that is:

$$Pi = Pe * Pl * Ps$$

Where:

Pi = Probability of instability

Pe = Probability of existence

Pl = Probability of length

Ps = Probability of sliding

The probability of existence (Pe) is a combined function of the joint spacing and the probability of occurrence for a specific joint set. The probability of sliding (Ps) is related to the shear resistance (a function of the joint strength and stress distribution) along the joint surfaces for a particular joint orientation. The end result of the Backbreak analysis is a cumulative distribution of expected BFAs. BFAs calculated in the analysis are defined as the angle from the bench toe to the bench crest after back break has occurred (effective BFA), as shown on Figure 5-1.

Using the bench configuration geometry, the cumulative BFA distribution can be converted into a distribution of expected catch-bench widths (CBW). Therefore, the probability of achieving a given BFA can also be defined as the probability of maintaining a specific CBW or better. This probability can be characterized as *reliability* and is determined by the following equation:

$$Reliability = 1 - CPLT$$

Where:

CPLT = Percentage that a BFA will be less than a given value

A CPLT of 20 percent on the cumulative BFA plot can be thought of as a reliability of 80 percent for the catch-bench width geometrically associated with that bench-face angle. Eighty-percent reliability means 80 percent of the time the CBW will be expected to meet or exceed the required bench width to contain rock fall (Figure 5-2).

5.1.2 Geologic Domains and Design Sectors

For Backbreak analysis, the ultimate pit design is divided into design sectors. Design sectors are areas in which the factors that control the back break angle are expected to be the same. Primary factors used in defining the limits of the design sectors are structural domain boundaries, pit wall orientation, and differences in rock type. The NAU mine designs have been divided into twenty-one design sectors which are presented in Figures 5-3 through 5-5 on maps of projected exposed geology. A summary of each sector's location, wall orientation, and rock type is presented in Table 5-1.

5.1.3 Required Catch-Bench Width

CNI uses a Modified Ritchie Criterion as a *guide* for designing catch-bench widths. This method evolved following publication of a technical paper by A. M. Ritchie in 1963 on the design of highway shoulders for catching rockfall off excavated and natural slopes. Ritchie's investigation was limited to a relatively small number of slope angle and slope height geometries and therefore requires extrapolation or site-specific calibration for use in open-pit mining. Because slope (bench) height is one of the most important controls on the distance a rock will

travel when detached from the bench, CNI has derived an empirical relationship between the slope height and average, or preferred, catch-bench width for design purposes at CCV:

Modified Catch-Bench Width Criteria at CCV

*Catch-bench width (feet) = 0.2*bench height + 12 feet*

So the required width for single and double benching:

*(Single-bench width) 19 feet = 0.2 * 35 feet + 12 feet*

*(Double-bench width) 26 feet = 0.2 * 70 feet + 12 feet*

5.1.4 Catch-Bench Reliability

Under ideal conditions (controlled blasting with vertical drill holes in unfractured rock), the BFA would be vertical. In actual conditions, however, the bench face breaks back to a flatter angle along preexisting jointing and blast-induced fractures. Uncontrolled blasting reduces rock integrity, resulting in further back break. Because of the variability in geologic structure, back break is not uniform and resulting BFAs are a distribution rather than a unique angle.

For any given ISA, the bench width is variable. Therefore, CNI believes a reliability-based approach is required to determine the distribution of catch-bench widths for ISA design. Catch-bench reliability refers to the percentage of time a catch-bench width will satisfy the *minimum* acceptable catch-bench width for a given bench height. Figure 5-2 illustrates this concept for 50% and 80% catch-bench width reliabilities.

Problems with controlled blasting and digging practices can necessitate the use of relatively high design reliabilities to achieve adequate catch-bench widths. Assuming proper controlled blasting and digging practices, CNI recommends using an 80-percent reliability of maintaining a catch-bench width of 19 feet for designing single (35-foot-high) benches or maintaining a catch-bench width of 26 feet for designing double (70-foot-high) benches. Industrywide, catch-bench reliabilities ranging from 60 to 90 percent have been used successfully. These minimum catch-bench width recommendations assume careful controlled blasting with scaling of loose material from the bench faces and clean benches prior to dropping to the next bench.

Higher reliabilities may be required in special circumstances, such as when double benching is considered to be less safe than single benching due to adverse structure geometries

that may create failure volumes that are difficult to manage at the double-bench height. In this case, it may be preferable to accept a lower reliability for mining single benches than to proceed with mining double benches, especially when the risk of mining under a large daylighted joint or fault is considered. Lower reliabilities may be acceptable when the mining increment is small, and mining advance is correspondingly rapid.

5.1.5 Catch-Bench Design

For bench-scale design, the maximum achievable ISA depends on the BFA that corresponds to the desired reliability for the design bench height. The 80 percent design requirement means 80 percent of the time single benches must achieve a catch-bench width of 19 feet and double benches must achieve a catch-bench width of 26 feet. Tables that list achievable ISAs corresponding to various BFAs and reliabilities are calculated from the predicted BFA distributions generated by the Backbreak analysis of the rock-fabric data. The achievable ISA given a particular BFA is calculated using the following equation.

Maximum ISA, Given a BFA

$$ISA = \tan^{-1}\left(\frac{BH}{CBW + \frac{BH}{\tan(BFA)}}\right)$$

Where:

ISA = interramp slope angle

CBW = catch-bench width

BFA = bench-face angle

BH = bench height

5.1.6 Double Versus Single Benching

In many cases, double benching allows for steeper ISAs than single benching for two primary reasons:

1. When the bench height is increased from 35 feet to 70 feet, the corresponding minimum catch-bench width required by the Modified Ritchie Criterion does *not* increase by a factor of 2 but only increases from 19 feet to 26 feet.

2. The distribution of the amount of back break, or the distance the slope crest breaks back beyond the shovel dig line, typically remains constant.

Because it is the effective bench angle that is measured (Figure 5-1), the achievable BFAs for double benches should, in theory, be steeper than those achievable for single benches. This should result in cumulative BFA distribution curves for double benches that are shifted to the right of the curves for single benches.

5.1.7 Double- and Triple-bench Offsets

Typically, when double or triple benches are mined a small offset (or "lip") of rock is left behind in between the benches because the drill rig used for presplitting cannot drill close enough to the toe of the first bench when drilling the holes for the second bench (Figure 5-6). The offset can be fully avoided if presplit holes are drilled to the full double-bench height (Figure 5-7). At Cripple Creek, pre-split holes are typically drilled to a length of 47 feet on the first drill pattern for a 70-foot double bench; using this method does not typically leave an offset at the mid-bench, but because the bottom of the second bench is not pre-split it is common to encounter hard toe. A photograph of hard toe observed in the WHEX mine is shown in Figure 5-8. The hard toe can be eliminated by either manual excavation with a top-hammer pick as a final mining pass, or by utilizing full 70-foot pre-splits. The offset and/or hard toe reduces the effective catch-bench width and decreases the ability of the bench to catch falling rock. An 8-foot double-bench offset was assumed for this analysis based observed offsets/hard toe in the WHEX mine.

5.2 Backbreak Analysis Parameters

Input parameters for the Backbreak analysis are summarized and discussed in the following sections. Mean orientations, spacing, lengths, and probabilities of occurrence calculated for each structure design set used in the analysis are presented in Appendix F.

5.2.1 Joint Orientations, Spacings, and Lengths

Joint set orientations, spacings, and lengths are estimated from cell mapping data collected in the WHEX mine by both CNI and CCV staff. Cell mapping locations and a summary of the structural data for the NAU mining areas are discussed in detail in Chapter 3 of this report. Cell mapping data is sorted according to rock type and orientation; only rock types

appearing in a given sector and structures with an orientation towards the excavation are considered for analysis in that sector. The distribution of joint set lengths and spacings are assumed to follow negative exponential distribution. The distribution of dip and dip direction of joint sets are assumed to follow a normal distribution.

5.2.2 Probability of Occurrence

The probability of occurrence is the chance that a joint set will be present on a given bench face over a 50-foot length. It is calculated by dividing the number of occurrences of a joint set by the total number of observation points. A probability of occurrence was calculated for each design set in every sector.

5.2.3 Joint Strength Parameters

Joint strength parameters used for the Backbreak analysis are presented in Table 5-2. The strengths were derived from laboratory small-scale direct-shear testing on core samples. A detailed explanation for the determination of these strength parameters is presented in Chapter 4. Fracture shear strengths are statistically sampled for the Backbreak analysis in order to model the full range of possible strength values. The power strength model with no cohesion intercept was utilized for the Backbreak analysis because a linear model tends to overestimate the shear strength of joints at the low normal stresses typically encountered at the bench scale.

5.2.4 Design Sets

Three design sets were designated for each sector based on the wall orientation being analyzed: left wedge, plane shear, and right wedge. The three design sets were further broken up into an upper and lower region to separate geologic sets, if present. The rock fabric data and design set statistics for Sector 1 are shown in Figure 5-9, and a summary of the design sets for all sectors can be found in Appendix F. In this analysis, all structure set types that fell into the design sets were used and considered as potential sliding planes. Joints to be included in a given design set were strictly determined by orientation relative to the wall orientation.

5.3 Calibration of Backbreak Analysis

Three bench-face angle distribution curves are used to calibrate the Backbreak analysis to a specific mine's blasting and excavation practices: measured, theoretical and predicted. The curves are defined below:

- **Measured Curve:** The measured BFA distribution is the actual measured field performance of excavated bench faces at CCV. Measured BFA data were taken in the field by CNI and CCV, and also by LiDAR (light detection and ranging) scans. The purpose of obtaining measured data is to calibrate the predicted curve results for the same bench height, rock type, and wall orientation.
- **Theoretical Curve:** The theoretical BFA distribution is produced by the Backbreak analysis by means of probabilistic simulation of the discontinuity sets in each design sector. The theoretical curve represents bench-face angles that would be achieved if benches could be mined with no disturbance. The theoretical curve is therefore always steeper than that observed in actual mined benches (measured curve).
- **Predicted Curve:** Experience has shown that theoretical BFAs are impractical to attain because of the effects of blasting, excavation practices, and complex failure modes not simulated by the Backbreak analysis. To account for effects caused by blasting and digging, an empirical shift has been developed to adjust the theoretical BFA curve to the predicted BFA curve. This empirical shift has been calibrated for various grades of blasting and excavation practice based on experience at hundreds of mines. However, when quality measured data is available such as at CCV, the theoretical to predicted shift can be calibrated to the specific blasting and excavation practices performed.

The Backbreak analysis was calibrated for one wall orientation in each geotechnical rock type. The calibration wall orientations were selected based on the quality and availability of measured bench-face angle performance data. The results of the calibration are presented in the bench-face angle distribution plots in Figure 5-10. There is an excellent correlation between the measured BFA data and the predicted BFAs from the Backbreak analysis. The careful blasting practices at CCV show that the mine is achieving better than predicted BFAs at reliabilities greater than 80%. At 80% reliability, the calibration is very good.

5.4 Discussion of Backbreak Results

The result of the Backbreak analysis is the predicted cumulative distribution of bench face angles for each design sector. The BFA distribution can be converted to a distribution of reliability that a specified catch-bench width will be achieved for a particular interramp slope angle. Based on the Backbreak results and bench-width reliability criteria discussed above, predicted maximum

single- and double-bench interramp slope angles for all sectors are presented in Table 5-1, along with the 3-17-15 NAU interramp slope design angle for each sector. The predicted achievable interramp slope angle for single- and double-benching for various reliabilities is plotted in Figures 5-11 through 5-14; the plots are limited to a maximum interramp slope angle of 56 degrees since this is the steepest angle that has successfully been mined at CCV while still achieving required catch-bench reliabilities. Current NAU design angles that are steeper than the predicted angles are shaded in red. The results are discussed by sector in the following sections.

5.4.1 Sectors One through Seven

Sectors one through seven are located in the Precambrian geotechnical rock type within the WHEX and Schist Island mines. Current design interramp angles do not meet the required 80% reliability in Sectors 1, 2, 6 and 7. It will be difficult to achieve adequate catch-bench widths with the currently proposed interramp slope angles in these sectors. These sectors should be modified to the appropriate recommended angles indicated in Table 5-1.

It may be possible that steeper interramp angles can be mined successfully in Sectors 2 and 6. Interramp angles in these sectors are controlled by foliation structures dipping towards the pit in the plane shear orientation. This foliation set is shown in the plot of Precambrian cell mapping data in Figure 5-9. However, it is possible that the foliation orientation in these areas may not be the same that was measured at the cell mapping locations in the WHEX. If benches exposed in these areas show foliation orientated at a more favorable orientation, there will be opportunity to steepen the interramp slope angles in these areas. As discussed in Chapter 3, a geotechnical televiewer hole (CPC14-1) was drilled in the Schist Island area and indicated that foliation would indeed dip towards the north; however, the drill hole was 1300 feet linear distance away from Sector 6 and as such the foliation encountered upon mining could be different than predicted.

5.4.2 Sectors 8 Through 21

Sectors 8 through 21 are located within the phonolite and Cripple Creek breccia geotechnical rock types within the WHEX, Globe Hill, and Schist Island mines. Current design angles are not steeper than the predicted maximum angles required in order to maintain adequate catch-bench widths and no modification is required at this time.

5.5 Upside Potential

There may be upside potential to some of the design interramp angles. In the CCV geology block model the Precambrian rock type is not differentiated into its various lithology types. As a consequence of this, all sectors in the Precambrian were assumed to have the joint shear strengths of schist, which is the most conservative assumption. This is the lowest strength tested of any rock type. If gneiss is exposed in Sectors 1 through 7 the results of the Backbreak analyses may be conservative in these areas.

As stated earlier in this chapter, because the bottom of the second bench is not typically shot with a pre-split hole it is common to encounter hard toe at the base of double benches. If the hard toe can be completely eliminated (either by manual excavation with a top-hammer pick or by utilizing full 70-foot pre-splits) an 8-foot offset would not be needed in the Backbreak analysis of double benches and steeper achievable double-bench interramp angles would result.

Optical scans of the constructed bench-face angles may be performed to evaluate catch-bench width performance. If performance of benches is shown to be better than predicted, interramp slope angles may accordingly be increased. These data may also be used to calibrate future Backbreak analysis at CCV.

.

Table 5-1. Recommended Maximum Interramp Slope Angles for the NAU Based On Bench-Scale Stability Analysis

Bench Analysis Sector	Wall Dip Direction	Rock Type	Location	3-17-15 NAU Design		Single Benching (35 foot)	Double Benching[3] (70 foot)
				Interramp Slope Angle	Single / Double Bench	*Maximum Interramp Slope Angle*	*Maximum Interramp Slope Angle*
1	264°	XGD	WHEX	45°	S	38°	46°
2	334°	XGD	WHEX	45°	D	33°	40°
3	230°	XGD	WHEX	45°	D	43°	51°
4	288°	XGD	WHEX	45°	D	37°	47°
5	123°	XGD	WHEX	45°	D	41°	50°
6	354°	XGD	Schist Island	51°	D	31°	40°
7	271°	XGD	Schist Island	52°	D	38°	49°
8	83°	TPH	Globe Hill	48°	D	42°	50°
9	355°	TPH	Globe Hill	46°/51°	D	42°	51°
10	209°	TBX	S.I. and G.H.	52°	D	45°	53°
11	299°	TBX	Schist Island	52°	D	43°	52°
12	94°	TBX	Globe Hill	52°	D	44°	52°
13	178°	TBX	Globe Hill	52°	D	45°	54°
14	350°	TBX	Globe Hill	51°	D	43°	52°
15	327°	TBX	WHEX	30°	S	44°	53°
16	75°	TBX	WHEX	51°	D	44°	52°
17	22°	TBX	WHEX	51°	D	43°	51°
18	267°	TBX	WHEX	52°	D	47°	55°
19	150°	TBX	WHEX	41°	D	44°	53°
20	166°	TBX	WHEX	45°	D	44°	53°
21	218°	TBX	WHEX	45°	D	46°	54°

Sectors with design angles (3-17-15 design) steeper than the maximum recommended interramp angle have a red fill

1. This table presents recommendations considering only the bench-scale analysis. Interramp and overall slope stability analysis may still limit maximum achievable interramp angles.

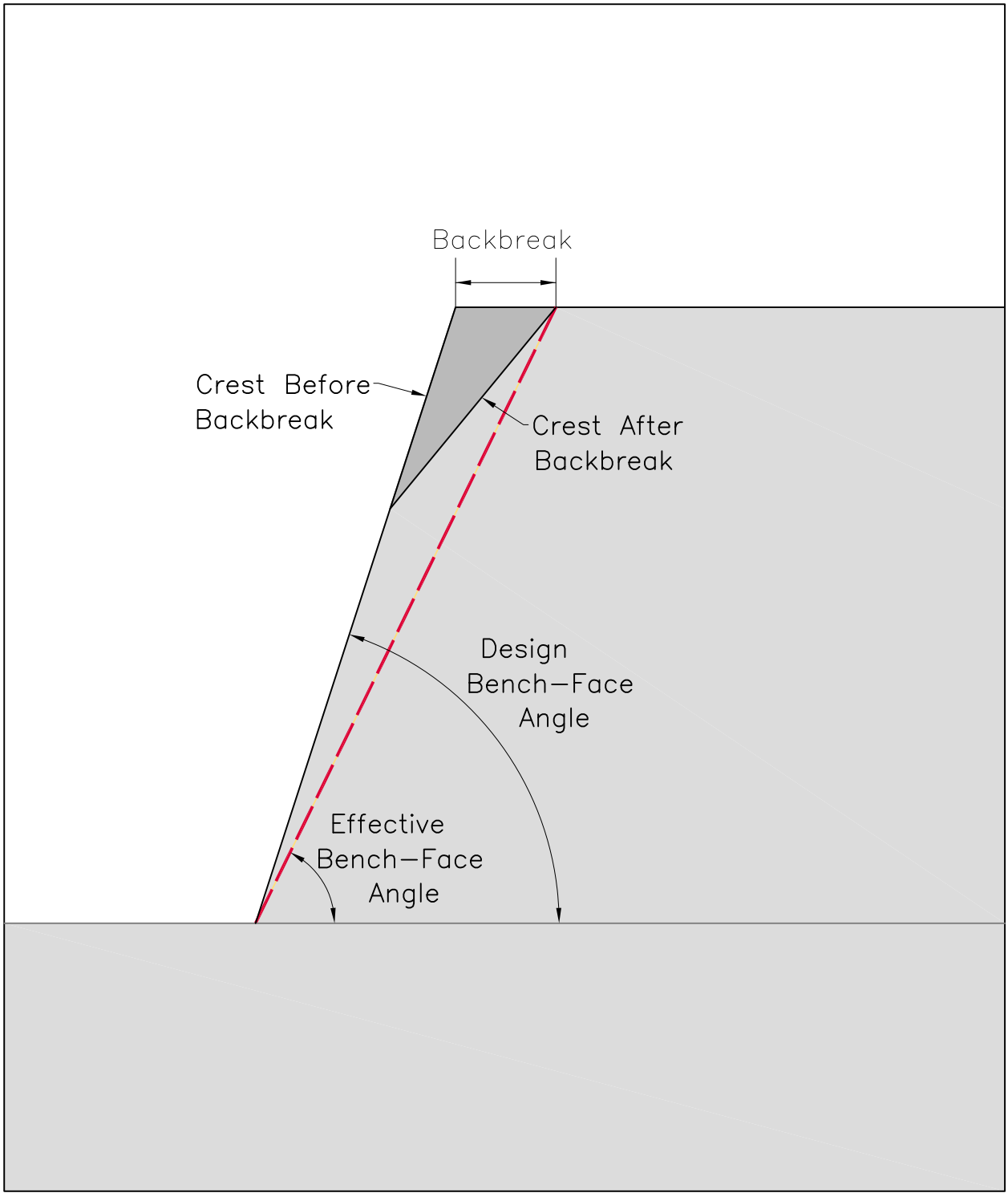
2. After excavation, back break along the bench crests will reduce the catch-bench widths to the required 80% reliability of achieving 19 feet for single benching and 26 feet for double benching.

3. An 8-foot offset was assumed for double benching based on observed performance at Cripple Creek. If the offset during mining is greater than 8 feet inadequate catch-bench widths will be achieved, and if the offset is less than 8 feet wider catch-bench widths will be achieved. The offset can be completely avoided (and steeper maximum interramp angles mined) if full 70-foot double-bench pre-splits are drilled.

Table 5-2. Fracture Shear Strengths Used in Backbreak Analysis

Rock Type	Rock Code	Linear				Power (Without Intercept)	
		Friction Angle (deg)	*Standard Deviation (deg)*	*Cohesion (psi)*	*Standard Deviation (psi)*	*K (for σ_n in psi)*	*M*
Cripple Creek Breccia	TBX	34.1	2.7	4.8	1.3	1.151	0.902
Phonolite	TPH	28.9	1.7	4.7	1.9	0.953	0.902
Pre-Cambrian	XGD	20.1	0.1	4.2	0.8	0.767	0.868

Note: The power (without intercept) shear strength model was employed for the Backbreak analysis



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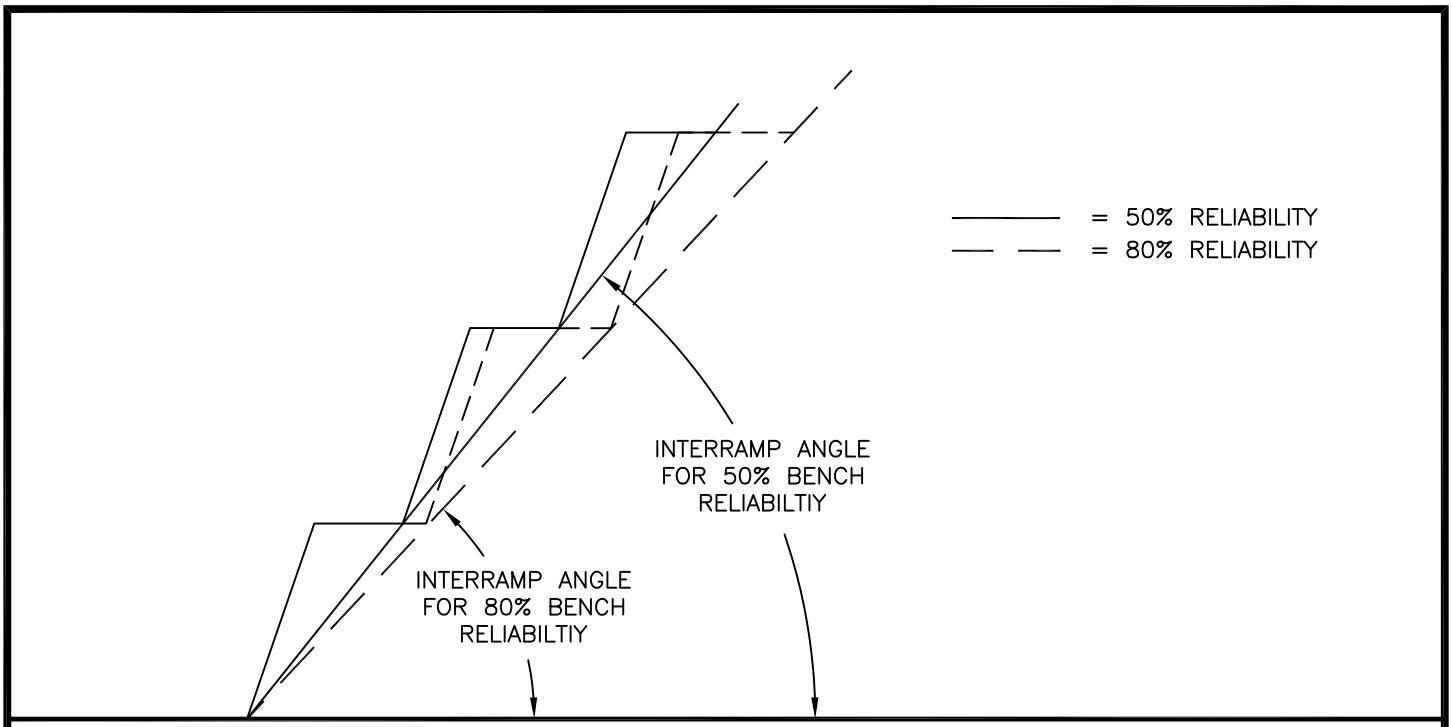
\2015\NAU_STUDY\REPORT\CHAP_5_BENCH-SCALE ANALYSIS\FIGURES\FIG 5-01 – BACKBREAK EXAMPLE.DWG

BACKBREAK ANALYSIS EFFECTIVE VERSUS DESIGN BFA

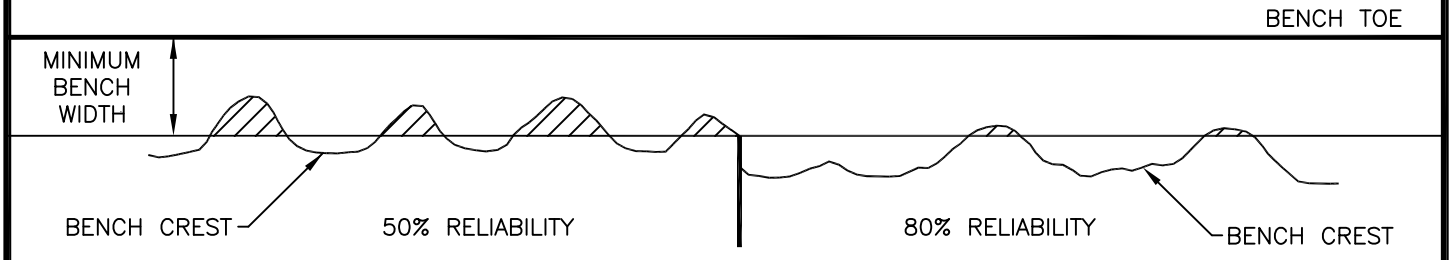
CRIPPLE CREEK & VICTOR

SCALE NTS

FIGURE 5-1

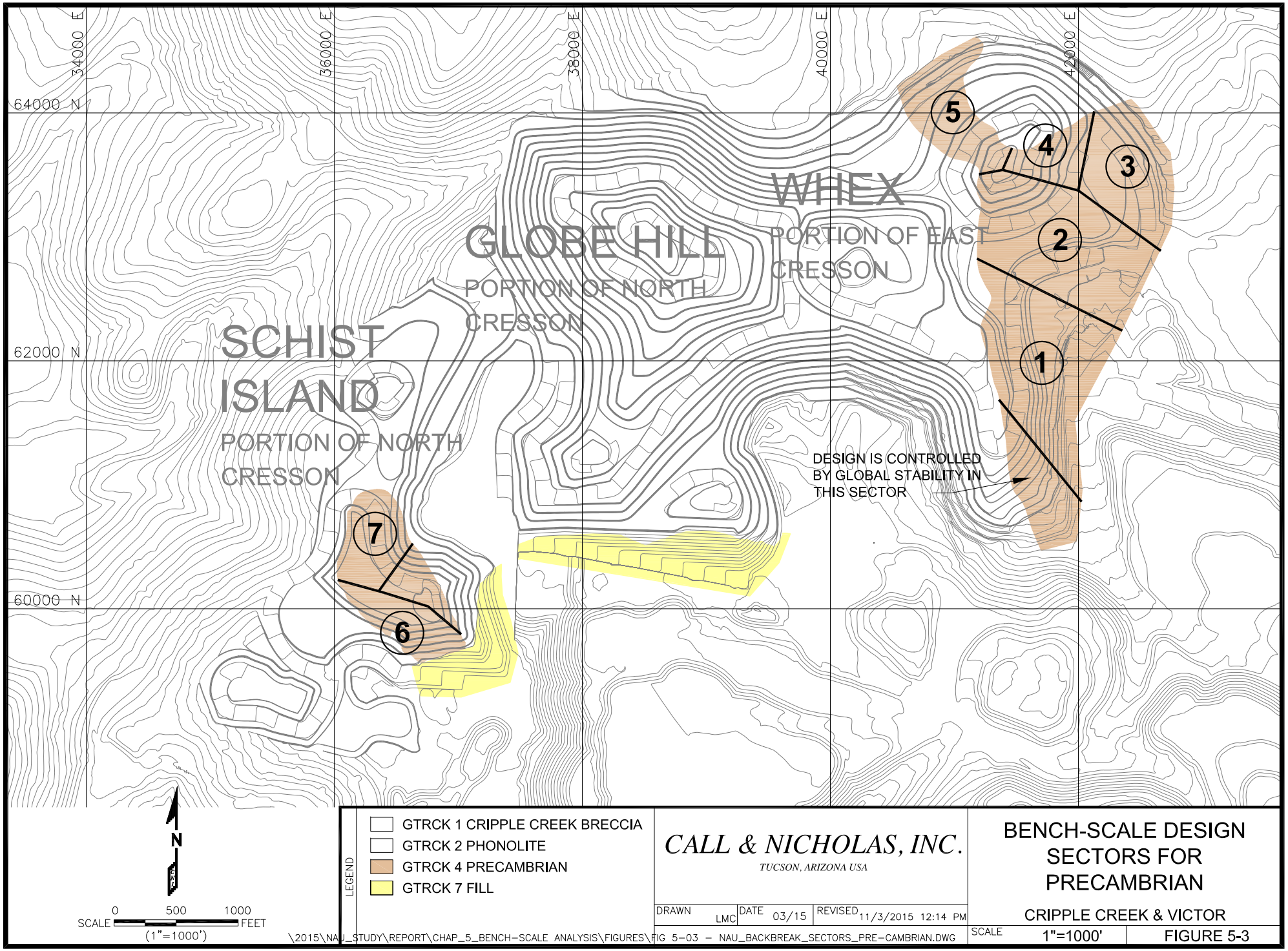


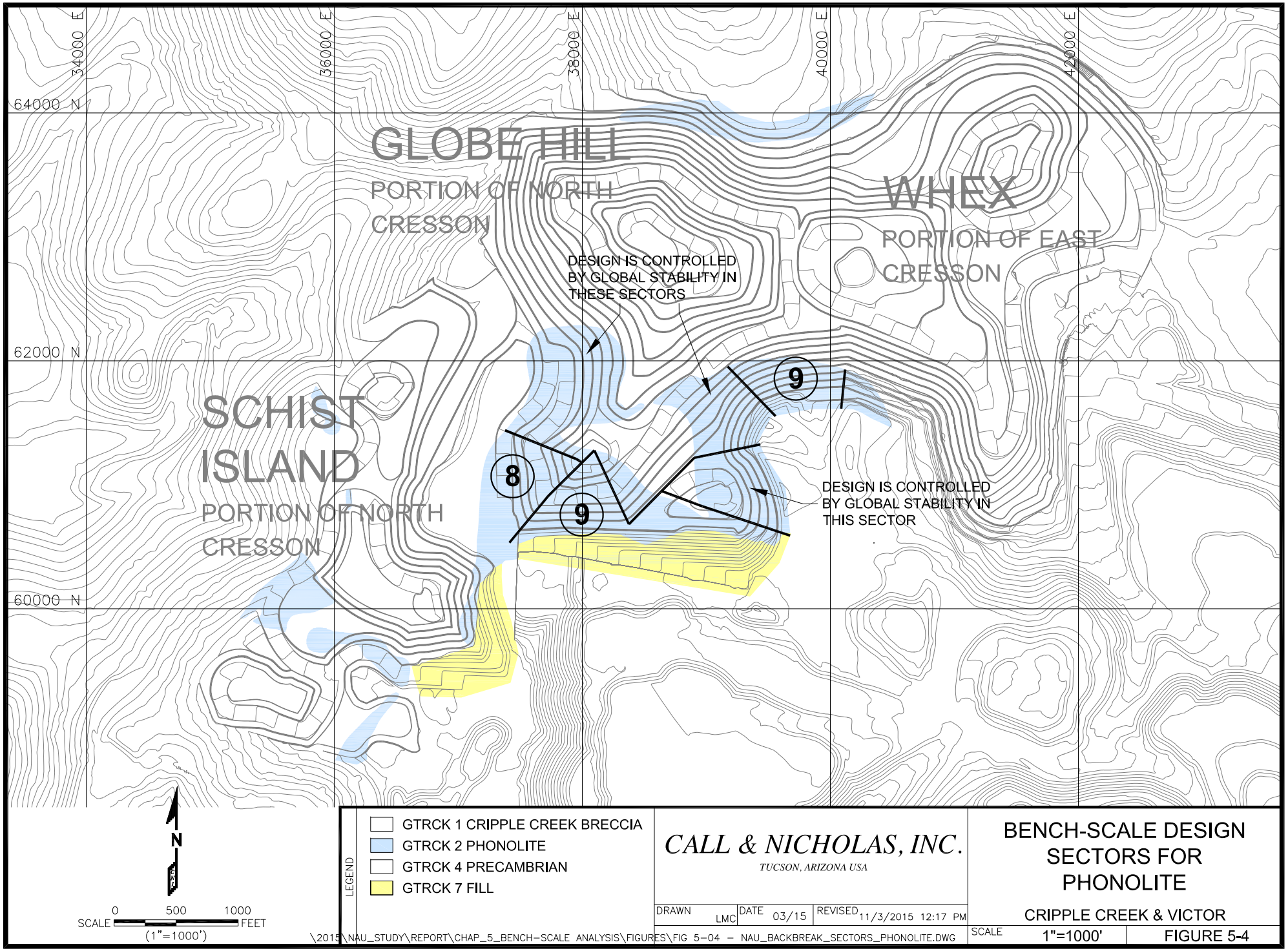
SECTION SHOWING INTERRAMP DESIGN BASED ON
50% AND 80% BENCH WIDTH RELIABILITY

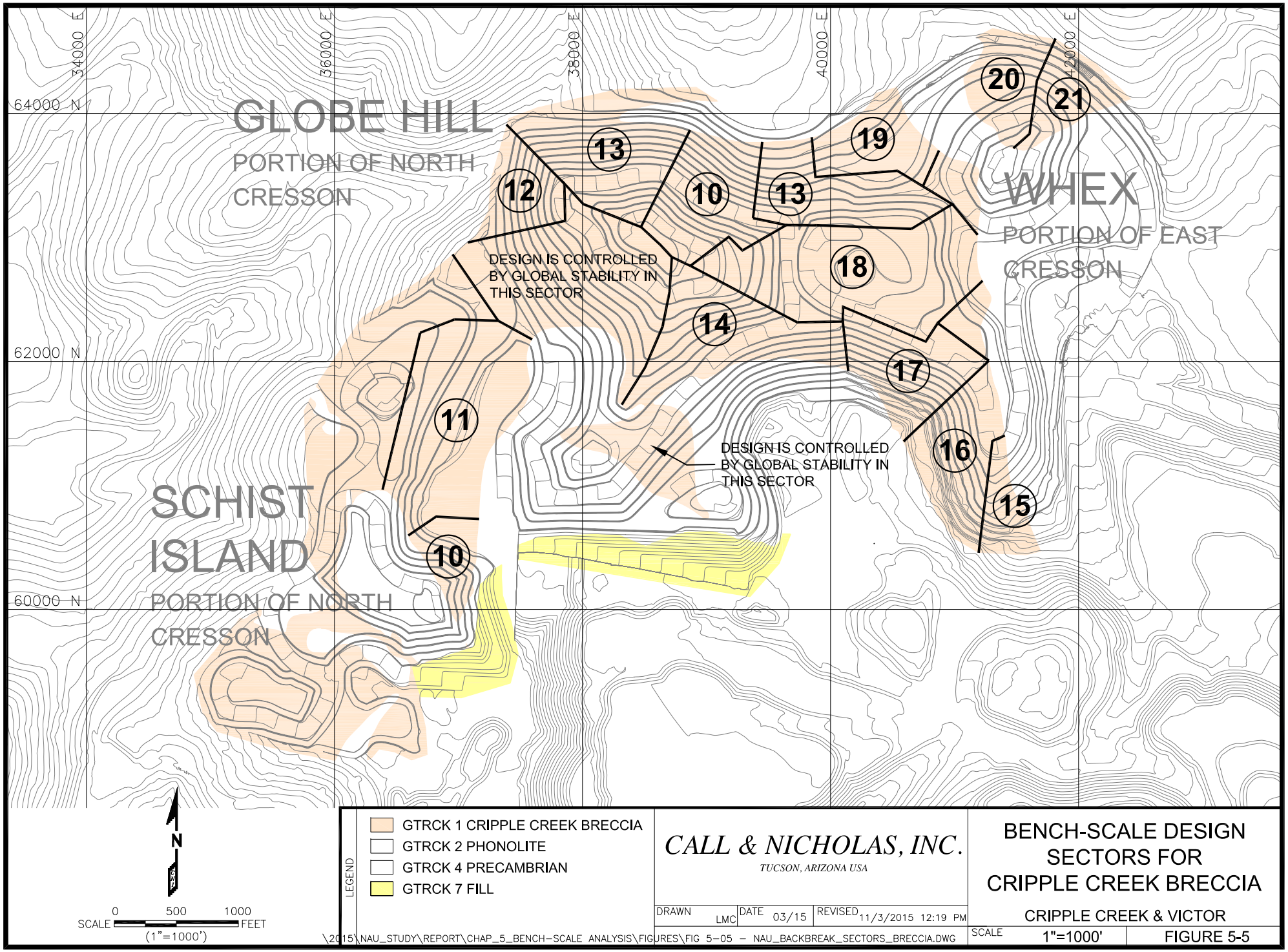


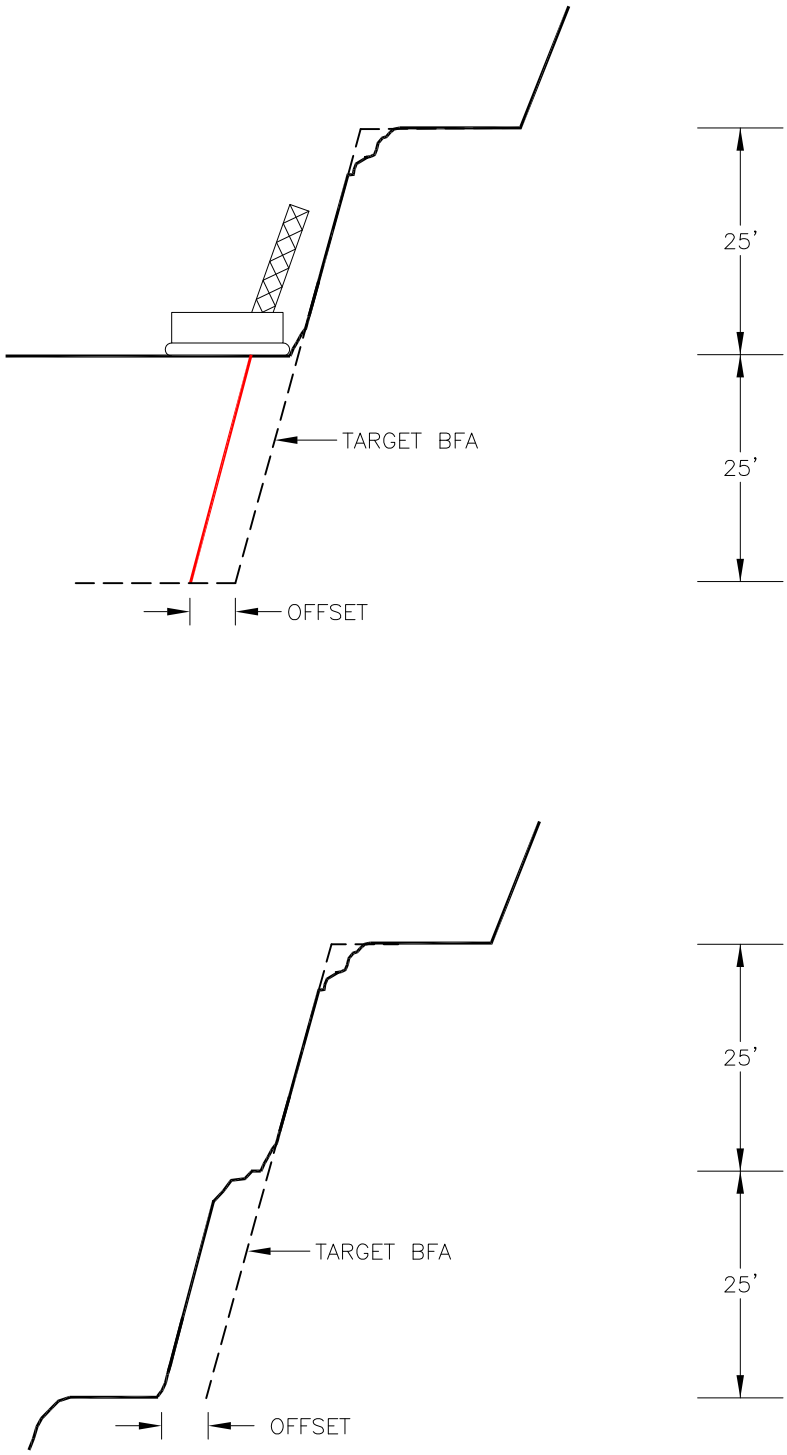
PLAN VIEW SHOWING DIFFERENCE BETWEEN A 50% AND
80% MINIMUN BENCH WIDTH RELIABILITY

Figure 5–2
Definition of Minimum Bench Width Reliability


34000 E
36000 E
38000 E
40000 E
42000 E
64000 N
62000 N
60000 N
GLOBE HILL
PORTION OF NORTH
CRESSON
WHIEX
PORTION OF EAST
CRESSON
SCHIST
ISLAND
PORTION OF NORTH
CRESSON
1
2
3
4
5
6
7
DESIGN IS CONTROLLED
BY GLOBAL STABILITY IN
THIS SECTOR
N
0
500
1000
SCALE
FEET
(1"=1000')
LEGEND
GTRCK 1 CRIPPLE CREEK BRECCIA
GTRCK 2 PHONOLITE
GTRCK 4 PRECAMBRIAN
GTRCK 7 FILL
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\2015\NAU_STUDY\REPORT\CHAP_5_BENCH-SCALE ANALYSIS\FIGURES\FIG 5-03 - NAU_BACKBREAK_SECTORS_PRE-CAMBRIAN.DWG
BENCH-SCALE DESIGN
SECTORS FOR
PRECAMBRIAN
CRIPPLE CREEK & VICTOR
SCALE 1"=1000'
FIGURE 5-3


34000 E
36000 E
38000 E
40000 E
42000 E
64000 N
62000 N
60000 N
GLOBE HILL
PORTION OF NORTH
CRESSON
WHEX
PORTION OF EAST
CRESSON
SCHIST
ISLAND
PORTION OF NORTH
CRESSON
DESIGN IS CONTROLLED
BY GLOBAL STABILITY IN
THESE SECTORS
DESIGN IS CONTROLLED
BY GLOBAL STABILITY IN
THIS SECTOR
8
9
9
N
0
500
1000
SCALE
FEET
(1"=1000')
LEGEND
GTRCK 1 CRIPPLE CREEK BRECCIA
GTRCK 2 PHONOLITE
GTRCK 4 PRECAMBRIAN
GTRCK 7 FILL
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\2015\NAU_STUDY\REPORT\CHAP_5_BENCH-SCALE ANALYSIS\FIGURES\FIG 5-04 - NAU_BACKBREAK_SECTORS_PHONOLITE.DWG
BENCH-SCALE DESIGN
SECTORS FOR
PHONOLITE
CRIPPLE CREEK & VICTOR
SCALE 1"=1000'
FIGURE 5-4


34000 E
36000 E
38000 E
40000 E
42000 E
64000 N
62000 N
60000 N
GLOBE HILL
PORTION OF NORTH
CRESSON
WHEX
PORTION OF EAST
CRESSON
SCHIST
ISLAND
PORTION OF NORTH
CRESSON
DESIGN IS CONTROLLED BY GLOBAL STABILITY IN THIS SECTOR
DESIGN IS CONTROLLED BY GLOBAL STABILITY IN THIS SECTOR
10
11
12
13
14
15
16
17
18
19
20
21
N
0
500
1000
SCALE
FEET
(1"=1000')
LEGEND
GTRCK 1 CRIPPLE CREEK BRECCIA
GTRCK 2 PHONOLITE
GTRCK 4 PRECAMBRIAN
GTRCK 7 FILL
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\2015\NAU_STUDY\REPORT\CHAP_5_BENCH-SCALE ANALYSIS\FIGURES\FIG 5-05 - NAU_BACKBREAK_SECTORS_BRECCIA.DWG
BENCH-SCALE DESIGN
SECTORS FOR
CRIPPLE CREEK BRECCIA
CRIPPLE CREEK & VICTOR
SCALE 1"=1000'
FIGURE 5-5



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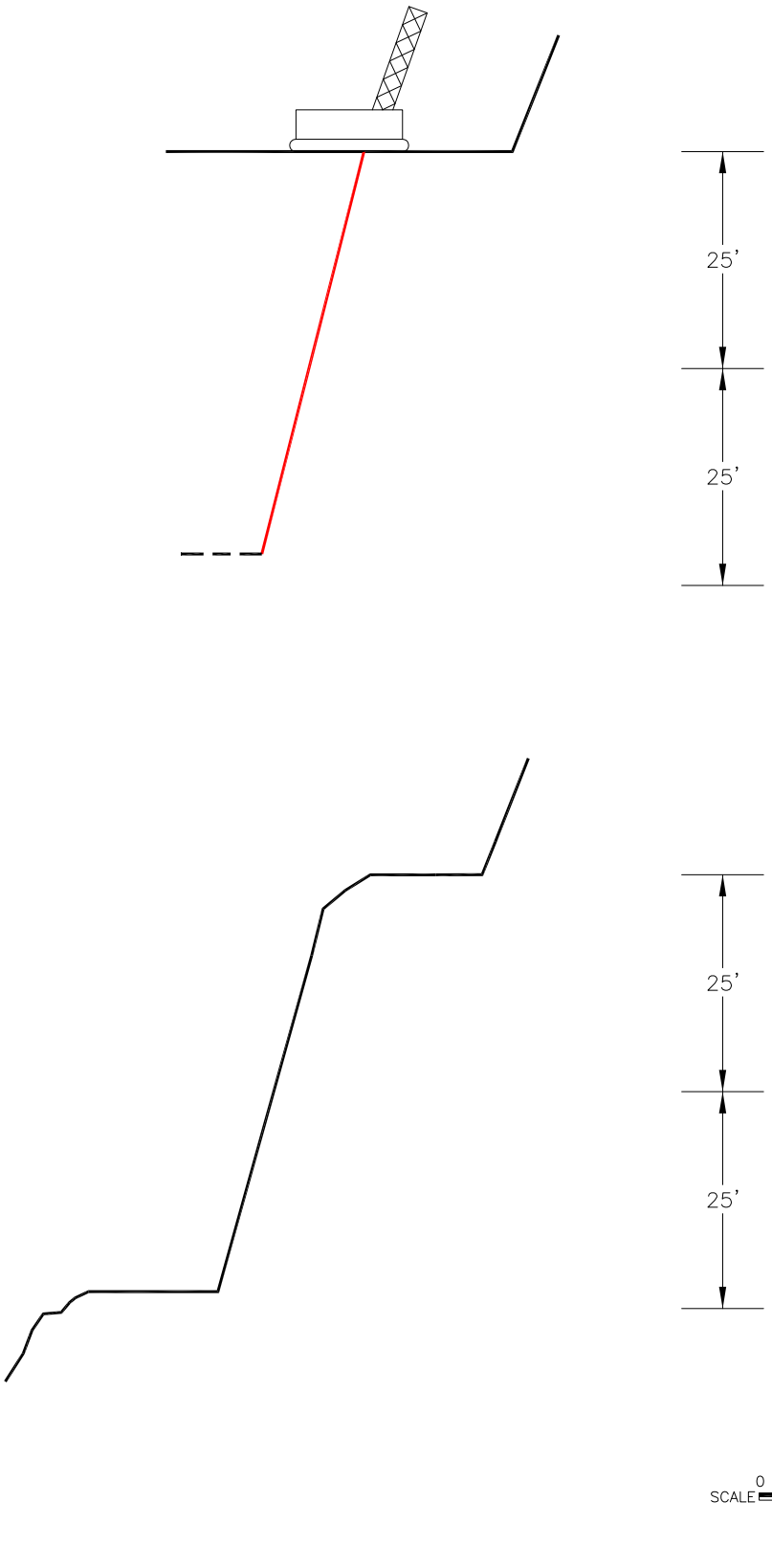
\2015\NAU_STUDY\REPORT\CHAP_5_BENCH-SCALE ANALYSIS\FIGURES\FIG 5-06 – DOUBLE PRESPLIT 1.DWG

OFFSET IN SINGLE- BENCH PRE-SPLITTING

CRIPPLE CREEK & VICTOR

SCALE 1:500

FIGURE 5-6



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\2015\NAU_STUDY\REPORT\CHAP_5_BENCH-SCALE ANALYSIS\FIGURES\FIG 5-07 – FULL DOUBLE PRESPLIT 2.DWG

DOUBLE-BENCH PRE-SPLITTING NO OFFSET

CRIPPLE CREEK & VICTOR

SCALE 1:500

FIGURE 5-7

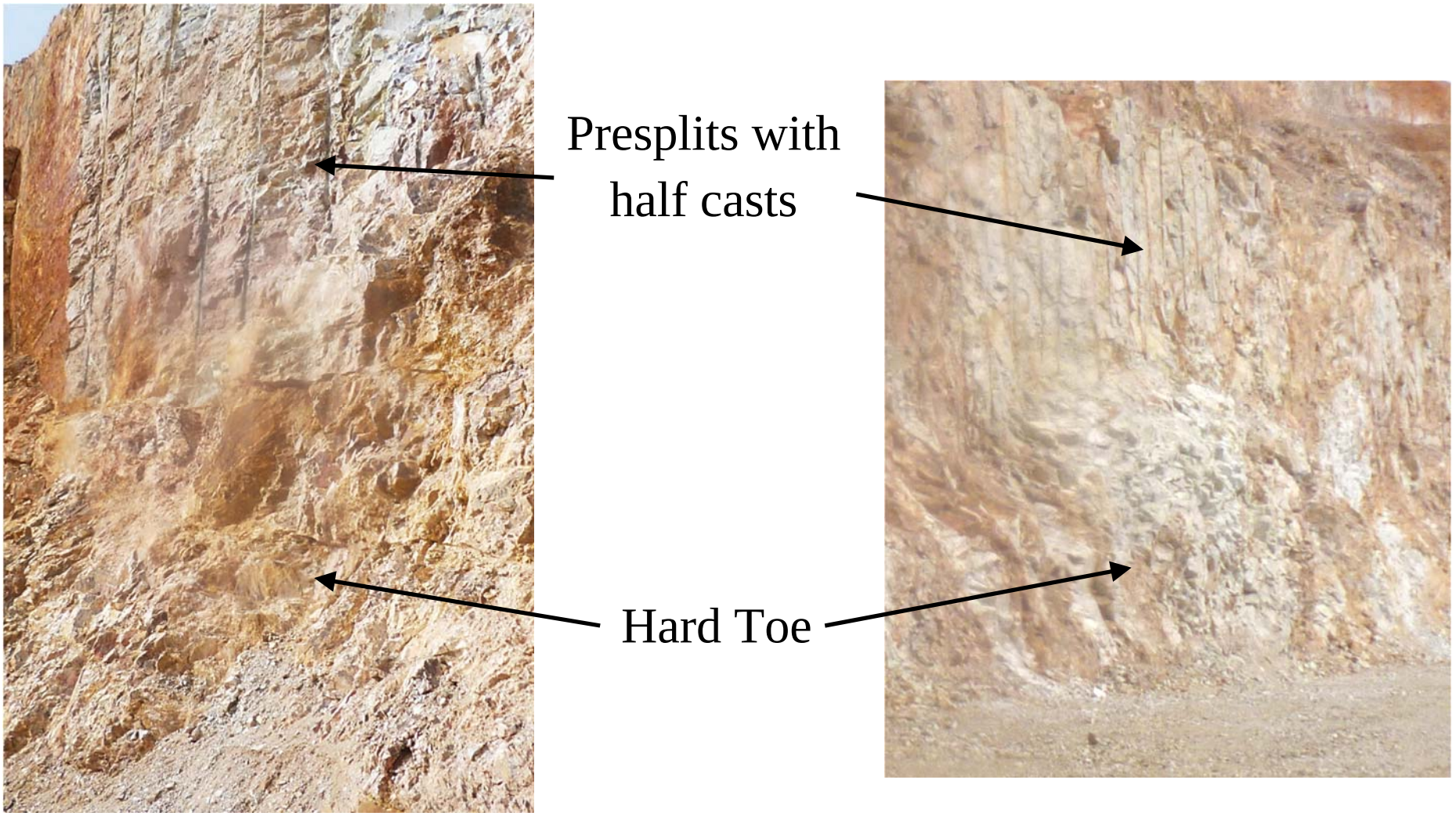
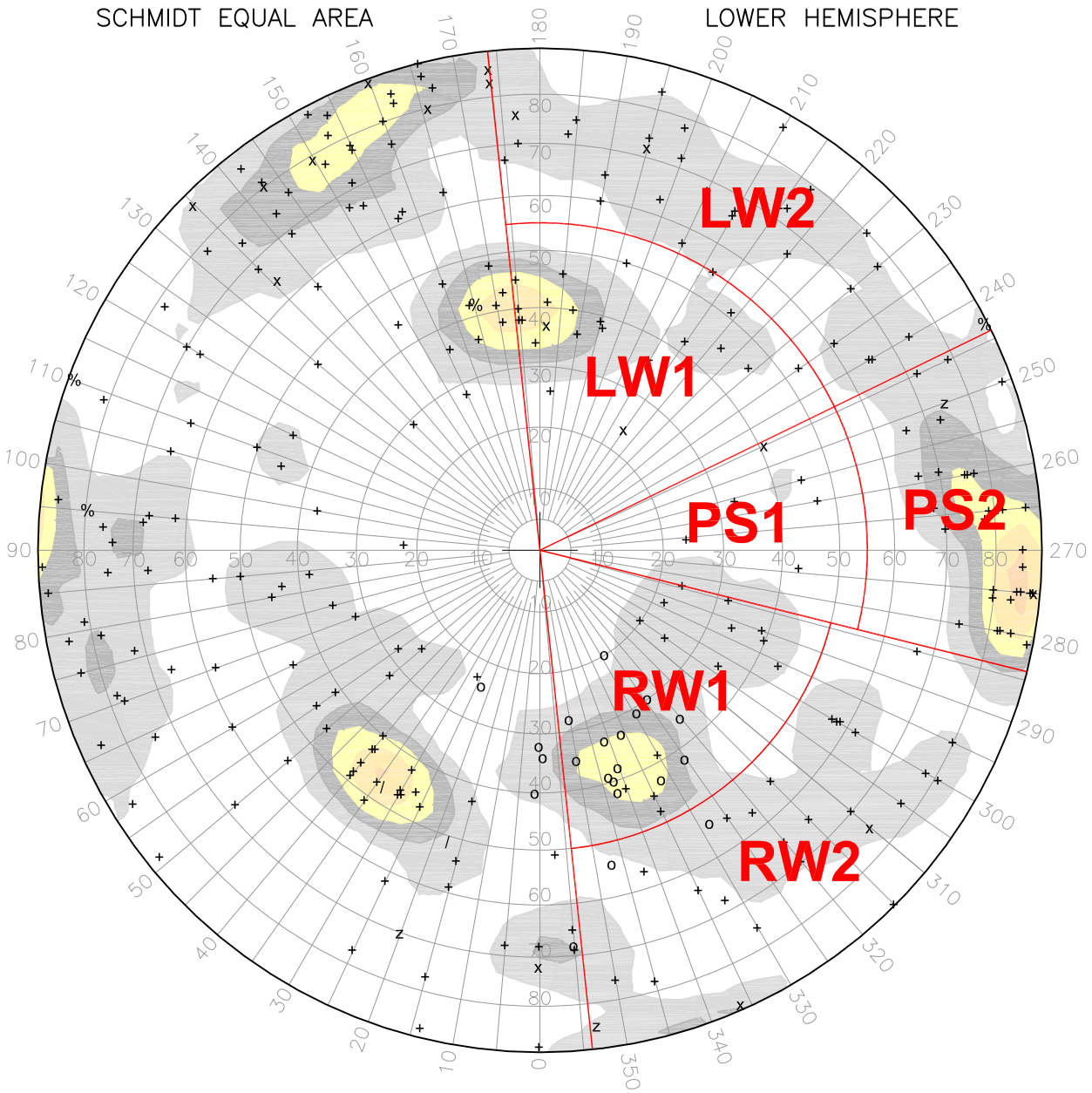


Figure 5-8. Hard Toe Observed in Double Benches With 47-foot Presplits on West Wall of the WHEX Mine, 10005 Elevation.



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PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 286

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	196.33	40.24	2.74	13.66	29.1%
LW2	205.31	71.22	2.73	12.89	52.7%
PS1	259.33	38.83	2.76	4.98	9.1%
PS2	266.48	79.55	3.31	14.60	58.2%
RW1	320.96	34.96	2.94	28.82	49.1%
RW2	319.07	68.61	3.15	16.00	41.8%

\2015\NAU_STUDY\REPORT\CHAP_5_BENCH-SCALE ANALYSIS\FIGURES\FIG 5-09 - SECTOR 1 XGD.DWG

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File: XGD.met

Figure 5-9.
Backbreak Design Sets and Statistics
Sector 1, Pre-Cambrian

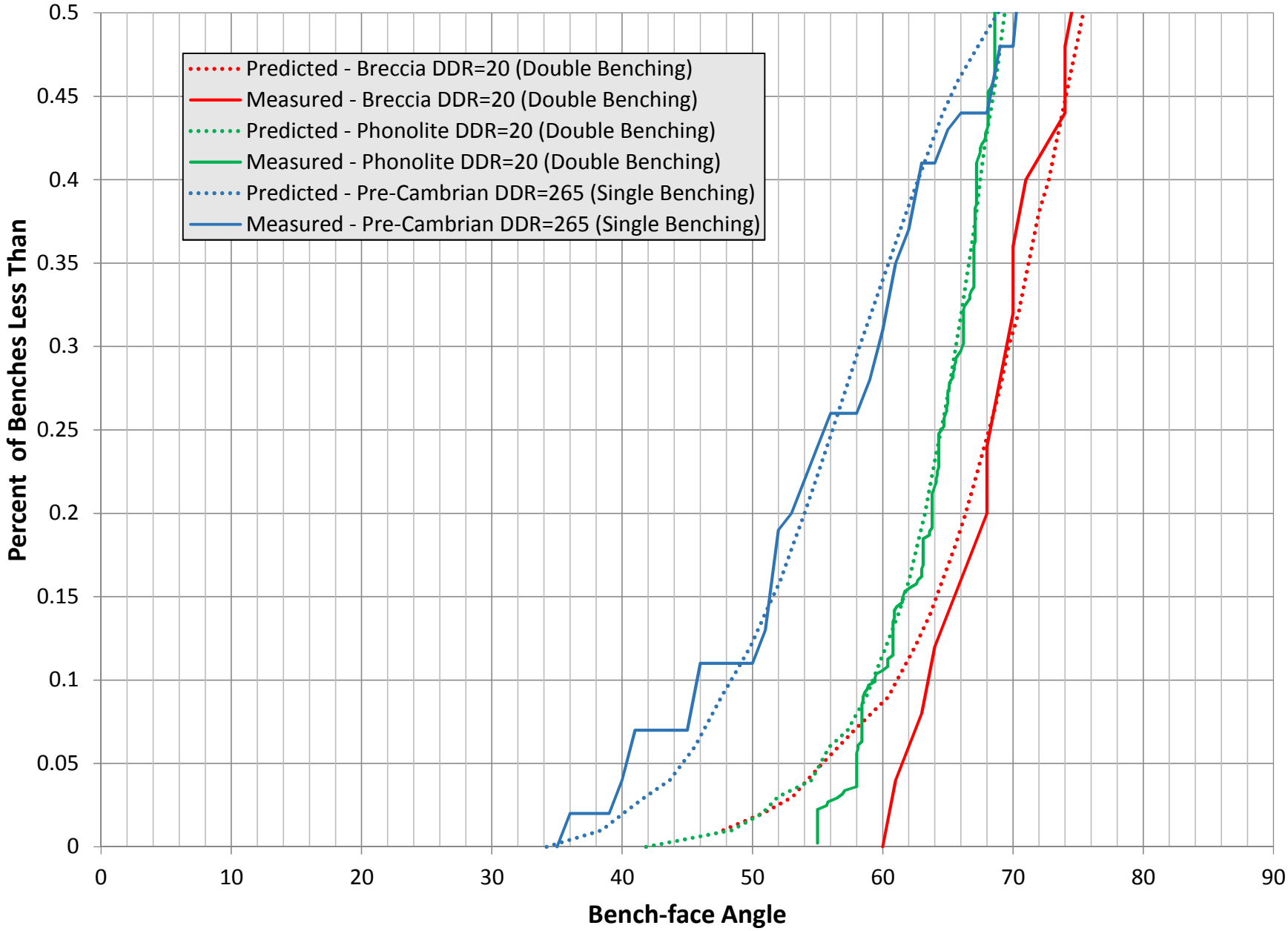


Figure 5-10. Cripple Creek Backbreak Calibration Results for Breccia, Phonolite, and Pre-Cambrian

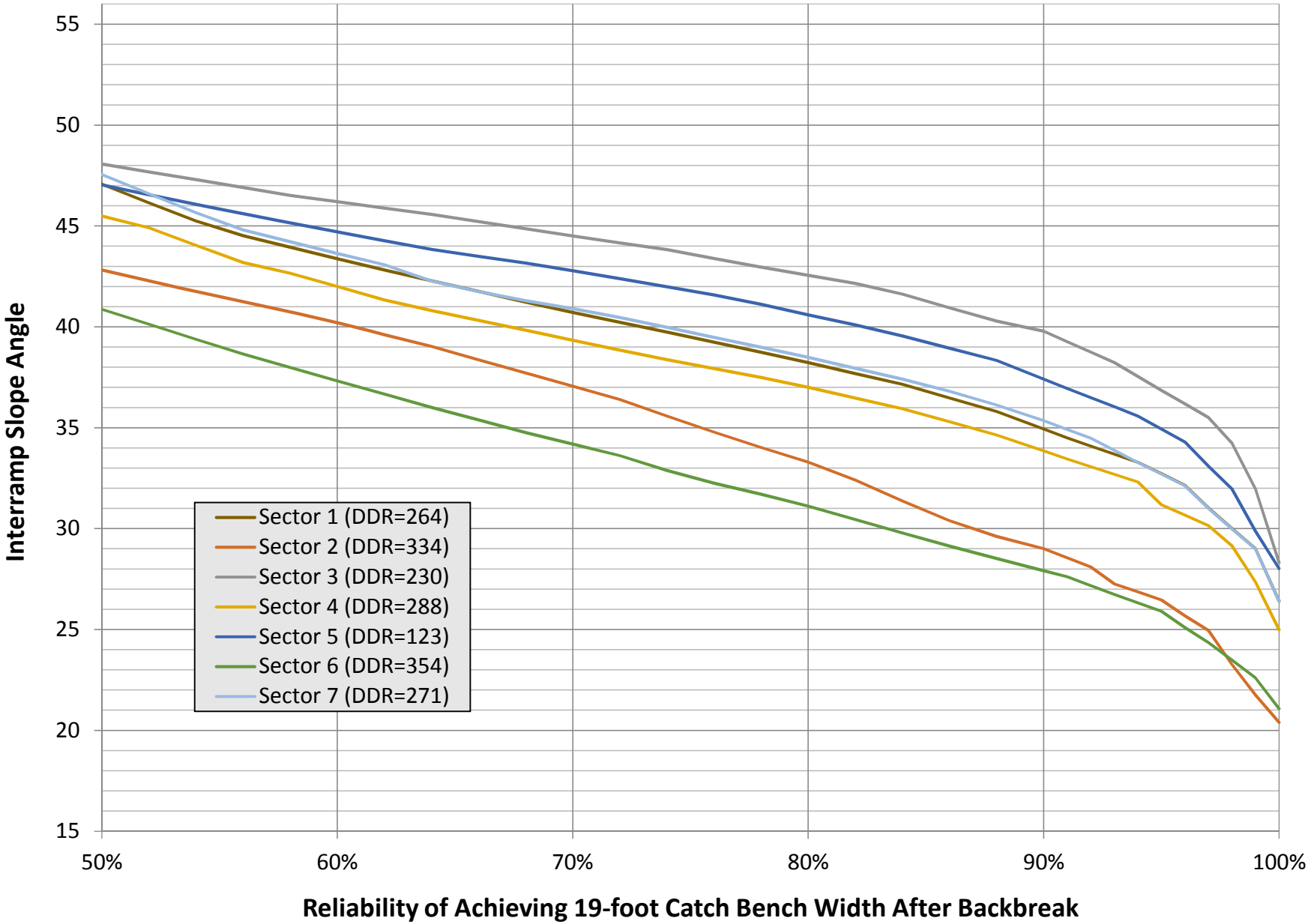


Figure 5-11. Cripple Creek Backbreak Results - Pre-Cambrian, Single Benching

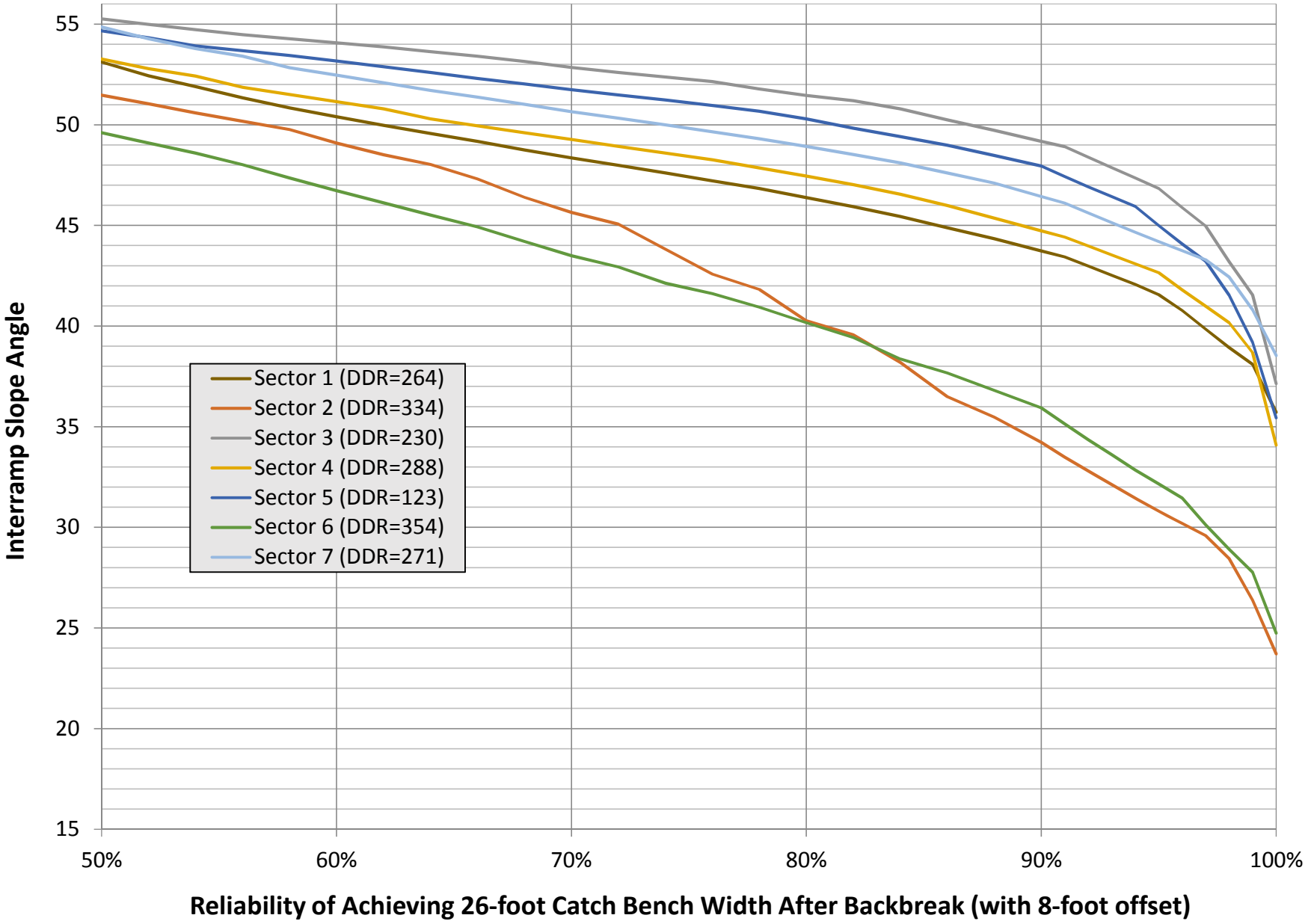


Fig 5-12. Cripple Creek Backbreak Results - Pre-Cambrian, Double Benching

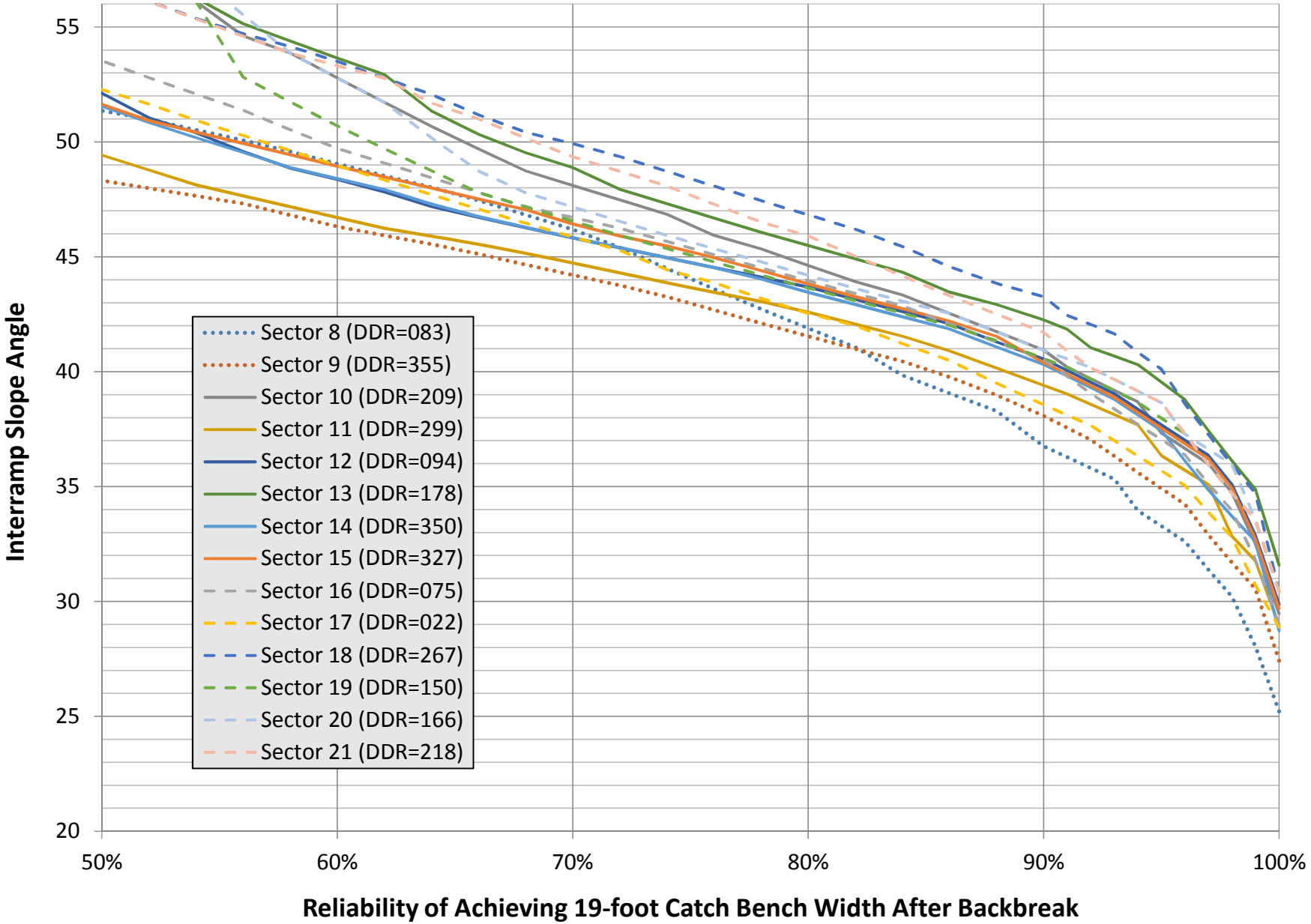


Figure 5-13. Cripple Creek Backbreak Results - Phonolite and Cripple Creek Breccia, Single Benching

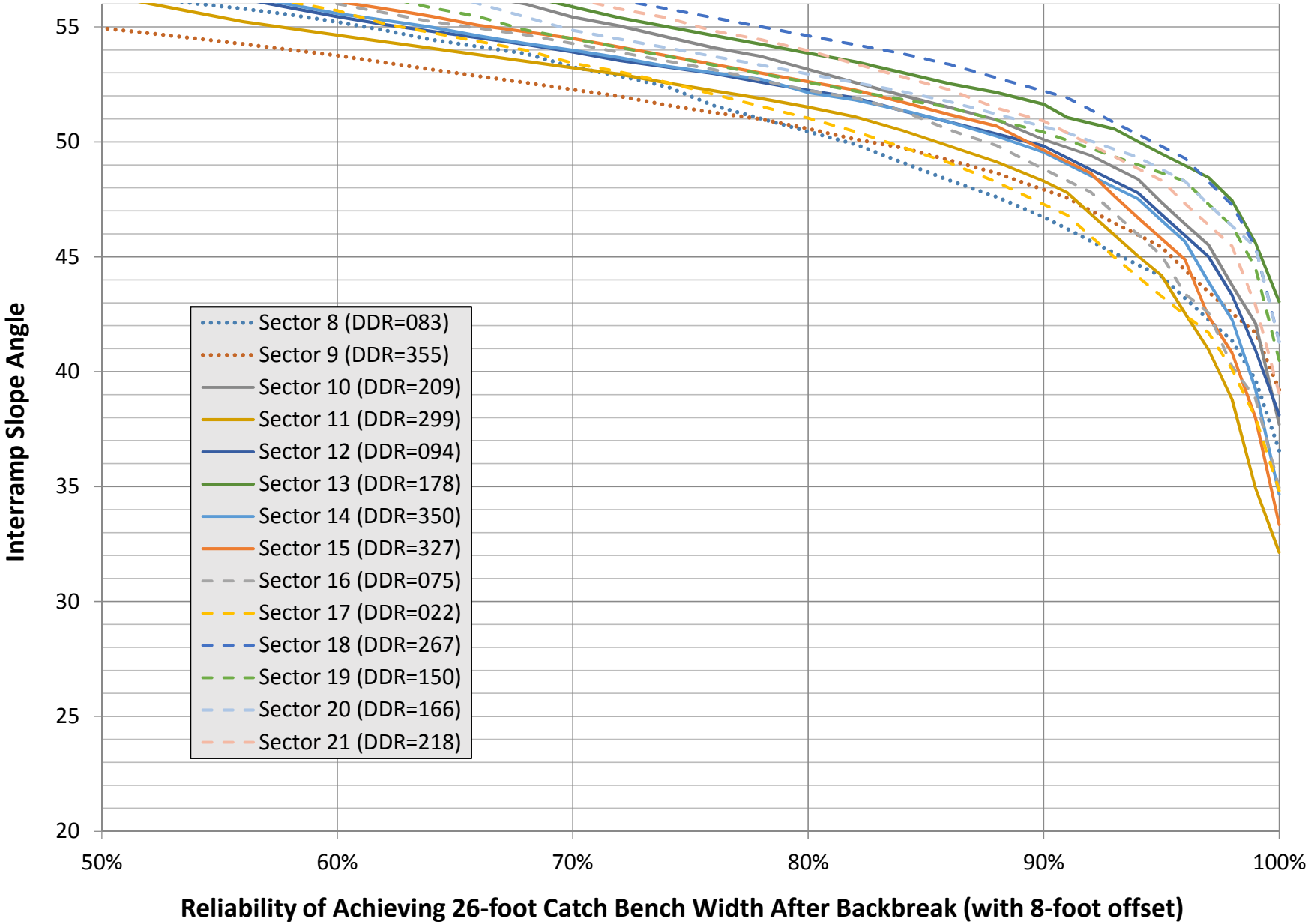


Figure 5-14. Cripple Creek Backbreak Results - Phonolite and Cripple Creek Breccia, Double Benching

6.0 GLOBAL SLOPE ANALYSIS

Global slope stability analyses were performed using the slope stability computer program, SLOPE/W©, which implements the limit-equilibrium method of slices. Ten cross sections were selected for analysis based on wall height, global slope angle, and rock mass quality. These ten cross sections are presented on plan maps of the NAU designs with projected exposed geology and RQD on Figures 6-1 and 6-2. The analysis methodology and results are presented below.

6.1 Discussion of Global and Interramp Stability at Cripple Creek

Global slope failures are defined as multi-bench instabilities that include shearing through rock mass, where stress levels in slopes locally exceed the rock-mass strength. To evaluate global stability the strength of the rock mass is compared to the predicted stresses based on geotechnical, geological, and geomechanical parameters. Global slope failures are generally associated with one or more of the following conditions:

- Major through-going structures that form daylighted or non-daylighted geometries in the mine wall
- Low rock-mass strength in the toe
- A ubiquitous pitward-dipping joint or foliation set
- High-angle faults or continuous joints that form back and side releases for slope movement
- Saturated toe, excess hydraulic gradients, and localized high pore pressures
- High in situ horizontal stresses

These factors, alone or in combination with high mine slopes, can create conditions that lead to global instability in the intermediate to ultimate mine walls.

At present time there is only one global-type slope instability at CCV, located in the south wall of the WHEX mine; a discussion of this instability follows in Section 6.1.1 below. Other multi-bench instabilities have occurred at CCV; however, these have been isolated events that were caused by single discrete structures. Interramp slope failures at CCV are typically not able to propagate more than two or three benches due to the limited continuity of major structures, and generally range in size from 2,000 to 10,000 tons. An example of an interramp instability that occurred in the Cresson mine in October 2012 is shown in Figure 6-3.

6.1.1 South WHEX Global Instability

The Precambrian schist in the south slope of the WHEX mine began to displace in January 2013 when the slope was only 125 feet high. The exposed geology in the south WHEX can be seen in Figure 6-1, and is defined by the contact between Precambrian schist to the east and Cripple Creek breccia and phonolite to the west. The instability was caused by pitward-dipping foliation structures in the schist that have been measured to dip to the north-northwest at 25 to 45 degrees. A stereonet plot of the structures mapped in the Precambrian rock in the WHEX is presented in Figure 6-4. In 2013 the slope was dozed down to an overall slope angle of 30 degrees; however, even after the dozing work the slope continued to displace. An overview photograph of the slope failure taken in 2014 is shown in Figure 6-5. A photograph of the foliation structures in the schist as observed at the toe of the slope on the 10110 level in 2014 is shown in Figure 6-6. Prism displacement vectors from 2014 in cross section are shown in Figure 6-7.

The overall slope angle in the south wall as of June 2015 was 28 degrees. As the slope displaces, it creates a buttress for itself while at the same time reducing the slope angle. The south WHEX instability is classified as a regressive type failure (Figure 6-8), which means that the slope may accelerate due to changes in conditions, but over time slope velocities will trend towards zero. The slope over the last two years has repeatedly shown this “stick-slip” type behavior where the slope responds to rainfall or mining at the toe with displacements, and then over time trends back towards a slow steady-state movement. The slope does not pose a significant risk of failure runout or a rock fall hazard due to its relatively shallow angle. The slope instability in the south WHEX will likely continue to propagate deeper with mining so long as the foliation continues to dip to the north between 25 and 45 degrees. Velocities will likely continue to be steady-state even at the reduced interramp angle of 30 degrees.

Thus far, CCV has been able to manage the slope instability with judicious monitoring practices. The most significant effects from the failure have been on the scheduling and mine planning of operations in the south WHEX.

A back analysis was performed in order to calibrate the anisotropic shear strength along foliation planes in the Precambrian schist. The anisotropic strengths resulting from the back analysis are shown in Figure 6-9. The foliation was assumed to provide an anisotropic weakness when the angle of the potential slip surface was between 25 to 45 degrees. This calibrated schist

anisotropy strength will be used for forward analyses when the foliation is expected to dip towards the excavation.

6.2 Global Slope Model Design Methodology

6.2.1 Material Properties

Material properties used for the stability analyses were derived from the rock-strength testing and characterization performed on drill core samples combined with the amount of rock-mass fracturing estimated from the RQD block model. A detailed explanation of the determination of these strength parameters is presented in Chapter 4.0. Rock-mass properties used in the analyses are summarized in Table 6-1. Rock-mass strengths for this analysis are considered *post-peak* strengths, and are therefore suitable for long term design.

6.2.2 Hydrology

Water pressures in the slopes for the global stability analysis are assumed to be drained and unsaturated. As discussed in Chapter 3, the Cripple Creek mining district is underlain by an extensive network of historic underground works from prior mining activity, including a series of tunnels designed specifically for water drainage. The drainage tunnels include the Moffat (approx. 9,000 feet elevation), the Roosevelt (approx. 8,000 feet elevation), and the 6.3-mile-long Carlton Drainage Tunnel (constructed between 1939 and 1941) driven from an elevation of 7000 feet. These drainage tunnels are assumed to effectively gravity drain the underground workings below the CCV pits to an elevation of 7,000 feet. Vertical permeability in the diatreme rock is also likely to be high based on the dominant jointing patterns, which also promotes drainage through the tunnels.

6.2.3 Selection of Cross Sections for Analysis

Ten cross sections were cut perpendicular to the NAU mine designs provided by CCV at the time of analysis. These cross sections are presented on the plan maps in Figures 6-1 and 6-2. These cross sections were selected based on the following criteria:

- Global slope height
- Global slope angle (OSA)
- Rock-mass strength

6.2.4 RQD Modeling and Lithology

As discussed in Chapter 4, CNI uses a combination of laboratory testing and the degree of in situ fracturing (RQD) to determine rock-mass strength. The RQD distribution for each cross section was estimated from the 2015 RQD block model discussed in Chapter 3. RQD estimations for the SLOPE/W runs were generated in MineSight® from three-dimensional solids extruded 50 feet perpendicular to the sections in both directions. The 70% reliability values of the RQD distributions were used for the analysis (i.e., 70% of measured RQD block values are greater than the value used). The 10 cross sections, along with the 3-17-15 NAU design shells, RQD block model, and drill-hole intercepts, can be seen on the odd numbered Figures between 6-11 and 6-29.

6.3 Global Stability Analysis Results

Results of the global stability analyses are summarized in Table 6-2. The critical failure surfaces identified are shown underlain by the lithology and 70th percentile RQD value on the even numbered Figures between 6-12 and 6-30. CNI typically considers a FOS above 1.20 appropriate for final wall mine slopes. Six of the ten cross sections resulted in a FOS lower than 1.20: GH-2, GH-3, GH-4, GH-5, SI-1, and WH-1. The low FOS values in the Globe Hill sections can be attributed to the weak and shattered rock mass in the Globe Hill Pipe zone. The low FOS values in sections SI-1 and WH-1 are caused by expected pit-ward dipping foliation structures in the Precambrian schist. Recommended interramp slope angles for each cross section are presented in Table 6-3.

All slopes are assumed to be completely depressurized by underground workings. If phreatic water pressures are encountered, the inputs to these analyses will need to be revisited.

A detailed description of the results and recommendations for each cross section follows.

6.3.1 Globe Hill Pipe Sensitivity Analysis

Since global slope angles are controlled by the weak Globe Hill pipe rock type, a sensitivity analysis was conducted in order to simplify the design process. The analysis considered various slope heights and pore pressure conditions and varied the overall slope angle until a FOS of 1.20 was achieved. The results of the sensitivity analysis are presented in Figure 6-10. It should be noted that the results are presented as overall slope angle, and that equivalent

design interramp slope angles will typically be one to two degrees shallower depending on the slope height and bench geometry.

6.3.2 Section GH-1

Section GH-1 is located on the south wall of the Globe Hill mine near the contact of the Globe Hill Pipe zone. The cross section has a total wall height of 560 feet, and a current design overall slope angle of 41 degrees. The wall is primarily composed of low RQD phonolite overlain by mine fill, with a small portion of Globe Hill Pipe at the toe (Figures 6-10 and 6-11).

The 3-17-2015 NAU mine shell yields a FOS of 1.87 which is above the required value of 1.20.

6.3.3 Section GH-2

Section GH-2 is on the southwest side of the Globe Hill mine. The cross section has a total wall height of 1050 feet and a designed overall slope angle of 42 degrees. The Globe Hill Pipe altered zone is the main rock type that will be exposed on the final mine wall. The RQD in the final wall is estimated to be zero percent based on the closest RQD model blocks and drill holes (Figures 6-12 and 6-13).

The 3-17-2015 NAU mine shell yields a FOS of 1.11, which is below the required FOS of 1.20. Using the design chart presented in Figure 6-9, the required interramp slope angles for the wall are 38 degrees for the portion above the ramp, and 44 degrees for the portion below the ramp.

6.3.4 Section GH-3

Section GH-3 is also on the southwest side of the Globe Hill mine. The cross section has a total wall height of 875 feet and a designed overall slope angle of 43 degrees. Globe Hill pipe is the main rock type that will be exposed on the final mine wall, with some higher RQD Cripple Creek breccia near the toe below the ramp. Typical RQD estimates for the slope range from zero to 20 percent (Figures 6-14 and 6-15).

The 3-17-2015 NAU mine shell yields a FOS of 1.06, which is below the required FOS of 1.20. Using the design chart presented in Figure 6-9, the required interramp slope angle for the wall in the Globe Hill pipe above the ramp is 39 degrees. The interramp slope angle can be raised to 44 degrees below the ramp where better quality rock is expected to be encountered.

6.3.5 Section GH-4

Section GH-4 is on the northeast side of the Globe Hill mine. The cross section has a total wall height of 1155 feet and is the highest designed wall for the NAU study. The geology consists of a zone of colluvium/weathered rock near the top of the slope, followed by moderate RQD phonolite, moderate RQD Cripple Creek breccia, and Globe Hill pipe in the toe of the slope (Figures 6-16 and 6-17).

The 3-17-2015 NAU mine shell yields a FOS of 1.52 for a slip surface passing the full slope height, and a FOS of 0.96 for a slip surface in the lower portion of the slope below the ramp in the Globe Hill pipe rock type. The interramp slope angle below the ramp must be reduced to 40 degrees in order to obtain a FOS of 1.20.

6.3.6 Section GH-5

Section GH-5 is on the southeast side of the Globe Hill mine. The cross section has a total wall height of 945 feet and a design overall slope angle of 42 degrees. Other than small layer of mine fill and colluvium at the top of the cross section, the entire slope is expected to be within the Globe Hill pipe (Figures 6-18 and 6-19).

The 3-17-2015 NAU mine shell yields a FOS of 0.96 for the upper portion of the slope and a 1.20 for the lower portion. The interramp slope angle in the upper portion of the slope must be lowered to 39 degrees in order to achieve a FOS of 1.20.

6.3.7 Section SI-1

Section SI-1 is on the south wall of the Schist Island mine. The cross section has a total wall height of 420 feet and a designed overall slope angle of 48 degrees. The wall is comprised of Precambrian schist overlain by mine fill and a small colluvium/weathered layer. Even though RQD data suggest good rock-mass quality (Figures 6-20 and 6-21), structural data from televiewer drilling in the area suggest that foliation in the schist will be dipping pitward just as in the current slope instability in the south WHEX. As such, the same anisotropic schist strengths that were developed from the back analysis were utilized for analysis in cross section SI-1.

The 3-17-2015 NAU mine shell yields a FOS of 0.46 for the slope as currently designed. As a sensitivity to reduction of the interramp angle, an interramp angle of 29 degrees was analyzed for this cross section. 29 degrees is the lowest angle possible before the bottom of the

current pit begins to be lost below the toe of the south wall. Even with an interramp reduction to 29 degrees, the FOS only increases to 0.72. If foliation is dipping into the excavation as predicted, the behavior of the slope will likely be very similar to the South WHEX instability, where the slope is mined at an interramp angle of approximately 30 degrees and the slope is continually in a state of regressive failure. However, if the slope is mined at an interramp angle of 30 degrees and is properly monitored and managed, it presents little risk to equipment or personnel due to its relatively flat slope angle.

6.3.8 Section SI-2

Section SI-2 is on the east side of the Schist Island mine. The cross section has a total wall height of 455 feet and an overall slope angle of 45 degrees. The slope is composed of Precambrian schist and Cripple Creek breccia, and is overlain by mine fill. The RQD in the final wall is estimated to be moderate to good (Figures 6-22 and 6-23).

The alteration is expected to yield a weaker rock mass, so strengths were reduced to correspond to the poor quality strengths used to evaluate the upper north wall of the WHEX mine as reported in the CNI report published in April 2011 entitled, *Cripple Creek and Victor Mine Wild Horse Extension Pit Design Slope Recommendations*. Table 6-1 lists the strengths used for the poor quality rock.

The 3-17-2015 NAU mine shell yields a FOS of 4.92 which is above the required value of 1.20.

6.3.9 Section WH-1

Section WH-1 is on the south side of the WHEX mine through the existing south WHEX slope instability. The cross section has a total wall height of 350 feet and an overall slope angle of 30 degrees. The geology in section WH-1 is Precambrian schist overlain by mine fill. Even though RQD data suggest good rock mass quality (Figures 6-24 and 6-25), foliation planes in the schist in this area of the pit are dipping to the north-northwest at 25 to 45 degrees. These foliation planes create a plane shear anisotropic weakness in the rock mass and allow sliding towards the excavation. The existing slope failure has been back analyzed as discussed in Section 6.1.1. The anisotropic strengths derived from the back analysis are used for the forward analysis of cross section WH-1.

The 3-17-2015 NAU mine shell yields a FOS of 0.64 for the slope as currently designed. As a sensitivity to reduction of the interramp angle, an interramp angle of 20 degrees was run for this cross section; even with a reduction to 20 degrees, the FOS only increases to 1.00. It is likely not economic to mine the slope at a significantly reduced interramp angle. However, if the slope is properly monitored and managed at its current interramp slope angle of 30 degrees, it presents little risk to equipment or personnel due to its relatively flat slope angle.

6.3.10 Section WH-2

Section WH-2 is on the southwest side of the WHEX mine. The cross section has a total wall height of 805 feet and an overall slope angle of 51 degrees. Cripple Creek breccica with moderate RQD is the main rock type that will be exposed on the final wall (Figures 6-26 and 6-27).

The 3-17-2015 NAU mine shell yields a FOS of 2.25 which is above the required value of 1.20.

6.3.11 Section WH-3

Section WH-3 is located on the northeast side of the WHEX mine. The cross section has a total wall height of 735 feet and an overall slope angle of 48 degrees. Cripple Creek breccica is the main rock type that will be exposed on the final wall. The RQD in the final wall is estimated to be 20 percent based on the closest RQD model blocks (Figures 6-28 and 6-29).

The 3-17-2015 NAU mine shell yields a FOS of 1.84 which is above the required value of 1.20.

Table 6-1. Rock Mass Properties (Isotropic)

Rock Type	Rock Code	GTRCK	RQD (%)	m_i	Density (pcf)	Elastic		Tensile Strength (psi)	Mean Strengths	
						Young's Modulus (psi)	Poisson's Ratio		Cohesion (psi)	Friction Angle (deg)
Cripple Creek Breccia	TBX (42)	1	90	13.9	150	1.36E+06	0.27	80	432	39.6°
			80	13.9	150	1.14E+06	0.28	56	333	38.9°
			70	13.9	150	9.24E+05	0.28	31	258	38.2°
			60	13.9	150	7.48E+05	0.28	22	199	37.7°
			50	13.9	150	5.71E+05	0.28	13	154	37.2°
			40	13.9	150	4.51E+05	0.29	10	119	36.8°
			30	13.9	150	3.31E+05	0.29	6	92	36.4°
			20	13.9	150	2.70E+05	0.29	5	71	36.1°
			10	13.9	150	2.09E+05	0.29	3	55	35.8°
Phonolite	TPH (21)	2	90	16.2	153	8.78E+05	0.21	10	390	38.4°
			80	16.2	153	6.80E+05	0.23	7	301	37.2°
			70	16.2	153	4.82E+05	0.24	4	232	36.1°
			60	16.2	153	3.85E+05	0.25	3	180	35.2°
			50	16.2	153	2.87E+05	0.26	2	139	34.4°
			40	16.2	153	2.51E+05	0.27	2	107	33.6°
			30	16.2	153	2.14E+05	0.28	1	83	33.0°
			20	16.2	153	1.95E+05	0.28	1	65	32.5°
			10	16.2	153	1.76E+05	0.30	1	50	32.0°
Lamprophyre	TLU (6)	3	90	7.1	173	4.69E+05	0.32	23	362	31.9°
			80	7.1	173	3.72E+05	0.33	17	280	31.1°
			70	7.1	173	2.74E+05	0.33	10	216	30.4°
			60	7.1	173	2.28E+05	0.34	8	167	29.8°
			50	7.1	173	1.82E+05	0.34	5	130	29.3°
			40	7.1	173	1.63E+05	0.34	4	101	28.9°
			30	7.1	173	1.43E+05	0.34	3	78	28.5°
			20	7.1	173	1.32E+05	0.35	2	61	28.2°
			10	7.1	173	1.20E+05	0.35	1	48	27.9°
Pre-Cambrian Schist	XBS (72)	4	90	21	176	3.53E+05	0.29	8	407	36.5°
			80	21	176	2.73E+05	0.30	5	314	34.5°
			70	21	176	1.93E+05	0.31	3	242	32.7°
			60	21	176	1.59E+05	0.33	2	187	31.2°
			50	21	176	1.26E+05	0.34	1	145	29.7°
			40	21	176	1.12E+05	0.35	1	112	28.5°
			30	21	176	9.74E+04	0.35	1	87	27.4°
			20	21	176	9.16E+04	0.36	1	67	26.4°
			10	21	176	8.58E+04	0.36	1	52	25.6°
Globe Hill Pipe	--	5	--	--	150	The Globe Hill Pipe Shear Strength is Modeled with a Power Curve Defined by $\tau=K*\sigma_n^m$, where K=1.707 (for σ_n in psi) and m=0.846				
Colluvium / Weathered	--	6	--	--	120	--	--	1	14	37°
Mine Backfill	--	7	--	--	120	--	--	1	5	37°

Table 6-2. Summary of 3-17-15 NAU Design Global Stability Analysis Results

Cross Section	Equivalent Backbreak Sector	3-17-15 NAU Design				Interramp Slope Angle Analyzed	Min. Factor of Safety	Figure #
		Total Wall Height (ft)	Overall Slope Angle	Interramp Slope Angle(s)	Bench (S/D)		Mean Strengths	
GH-1	9	560	41°	46°-51°	D	46°	1.87	6-12
GH-2	N/A	1050	42°	43°	D	43°	1.11*	6-14
GH-3	N/A	875	43°	45°	D	45°	1.06*	6-16
GH-4	10	1155	46°	52°	D	52°	0.96*	6-18
GH-5	N/A	945	42°	39°-52°	D	39°-52°	0.96*	6-20
SI-1	6	420	48°	51°	D	51° 29°	0.46 0.72†	6-22 --
SI-2	7, 10	455	45°	52°	D	52°	4.92	6-24
WH-1	N/A	350	30°	30°	S	27° 20°	0.64 1.00†	6-26 --
WH-2	17	805	51°	51°	D	51°	2.25	6-28
WH-3	21	735	48°	42°-50°	D	42°-50°	1.84	6-30

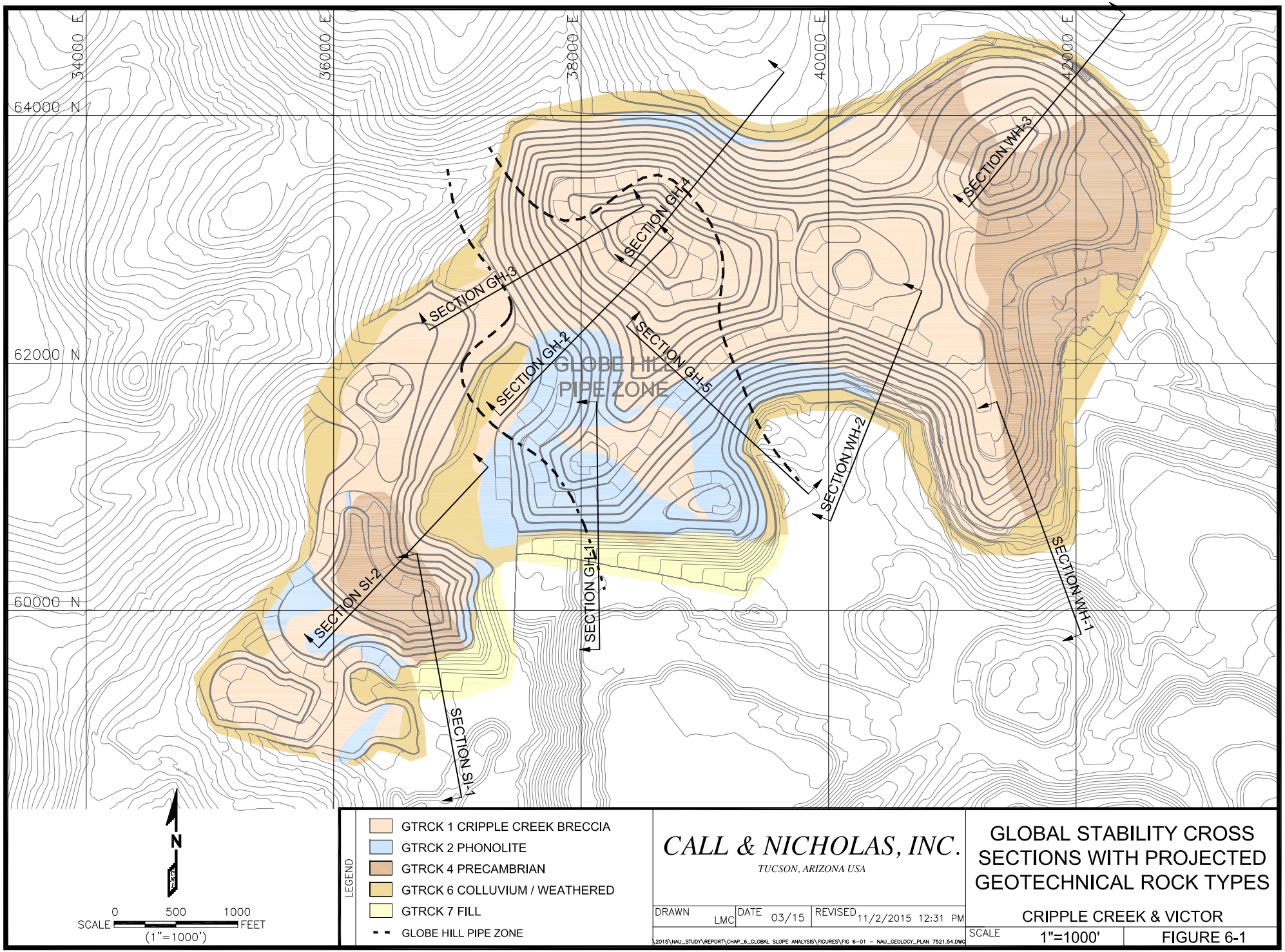
*The sensitivity analysis presented in Figure 6-10 can be used to determine the required slope angle to achieve a factor of safety of 1.20 for slopes within the Globe Hill Pipe zone.

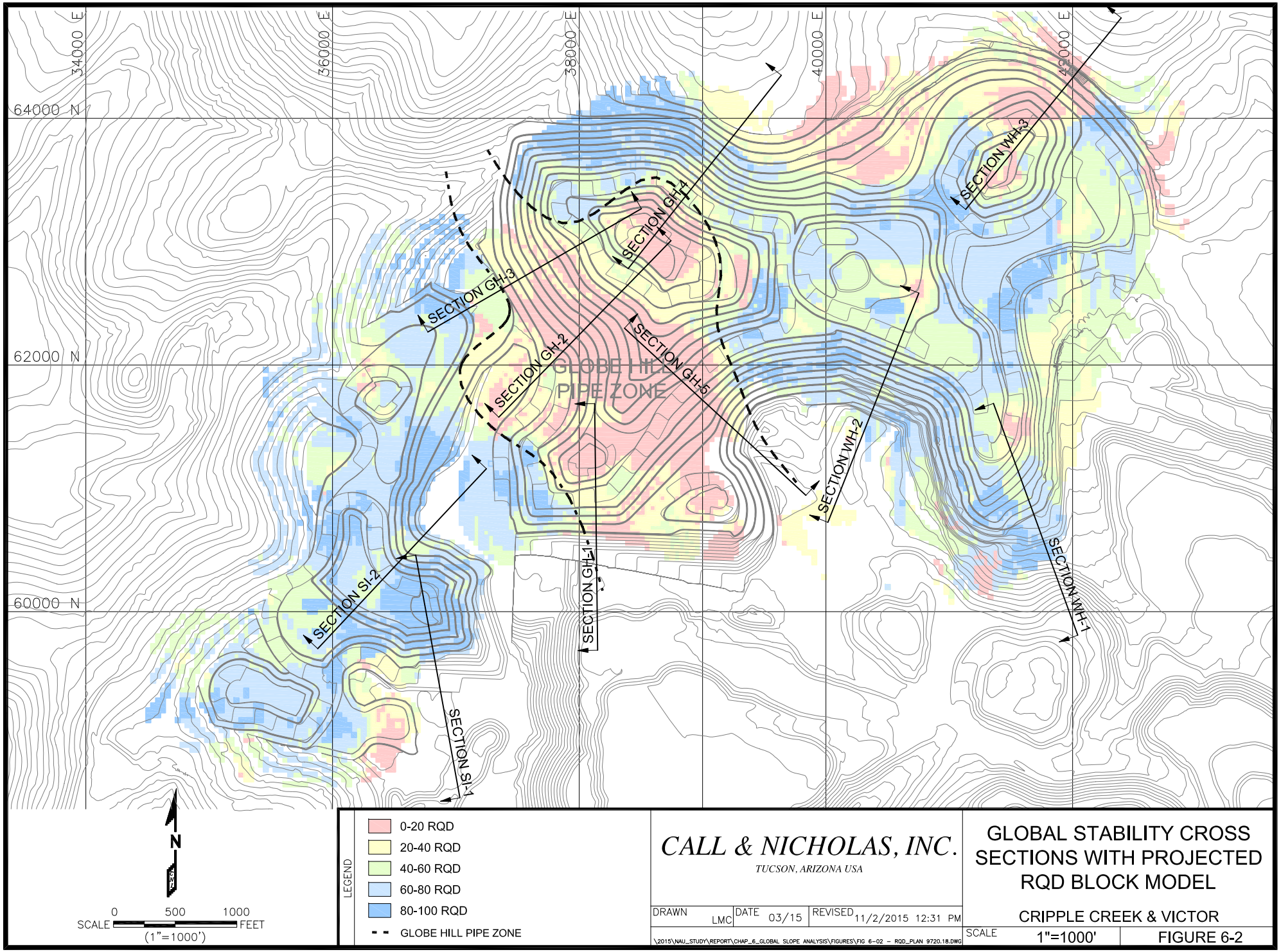
†South walls mined in Precambrian rock may fail along foliation and cannot be stabilitzed by reducing the interramp slope angle (from an economic perspective). It will likely be required to anitcipate failure and mitigate, monitor, and manage slope displacements in real-time as they occur.

Table 6-3. Recommended Interramp Slope Angles Based On Global Stability

Cross Section	**3-17-15 NAU Design** Interramp Slope Angle(s)	Recommended Interramp Slope Angle(s) Based on Global Stability Analysis
GH-1	46°-51°	No Modification Required
GH-2	43°	38° above the ramp, 44° below the ramp
GH-3	45°	39° above the ramp, 44° below the ramp
GH-4	52°	40° below the ramp
GH-5	39°-52°	39° above the ramp
SI-1	51°	30° †(see note below)
SI-2	52°	No Modification Required
WH-1	30°	No Modification Required †(see note below)
WH-2	51°	No Modification Required
WH-3	42°-50°	No Modification Required

†South walls mined in Precambrian rock may fail along foliation and cannot be stabilitzed by reducing the interramp slope angle (from an economic perspective). It will likely be required to anitcipate failure and mitigate, monitor, and manage slope displacements in real-time as they occur.


34000 E
36000 E
38000 E
40000 E
42000 E
64000 N
62000 N
60000 N
SECTION GH-3
SECTION GH-4
SECTION GH-2
SECTION GH-5
SECTION WH-3
SECTION WH-2
SECTION WH-1
SECTION GH-1
SECTION SI-2
SECTION SI-1
GLOBE HILL
PIPE ZONE
N
0
500
1000
SCALE
FEET
(1"=1000')
LEGEND
GTRCK 1 CRIPPLE CREEK BRECCIA
GTRCK 2 PHONOLITE
GTRCK 4 PRECAMBRIAN
GTRCK 6 COLLUVIUM / WEATHERED
GTRCK 7 FILL
GLOBE HILL PIPE ZONE
CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA
DRAWN LMC
DATE 03/15
REVISED 11/2/2015 12:31 PM
\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-01 - NAU_GEOLOGY_PLAN 7521.54.DWG
GLOBAL STABILITY CROSS SECTIONS WITH PROJECTED GEOTECHNICAL ROCK TYPES
CRIPPLE CREEK & VICTOR
SCALE 1"=1000'
FIGURE 6-1



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\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-02 - RQD_PLAN 9720.18.DWG

GLOBAL STABILITY CROSS SECTIONS WITH PROJECTED RQD BLOCK MODEL

CRIPPLE CREEK & VICTOR

SCALE 1"=1000'

FIGURE 6-2



Figure 6-3. Example Interramp Scale Instability, East wall Cresson Mine, El. 9690

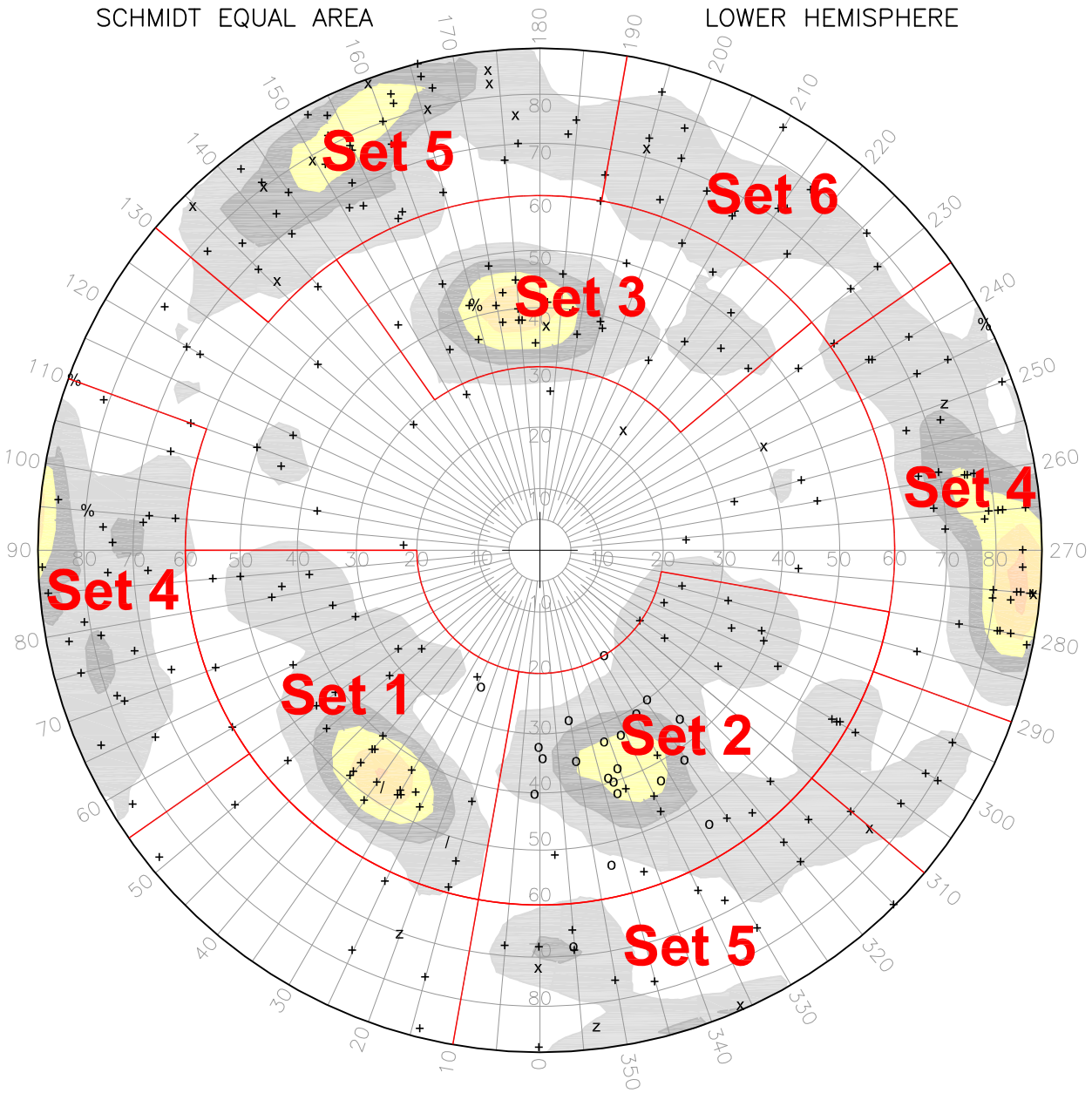


Figure 6-4.
WHEX Mine Cell Mapping Data
Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 286

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
Set1	45.59	43.65	5.48	25.88	54.5%
Set2	324.44	40.02	2.75	26.84	69.1%
Set3	186.14	42.31	3.31	13.09	43.6%
Set4	264.51	89.08	3.15	17.33	100.0%
Set5	157.23	86.77	2.87	14.53	72.7%
Set6	182.35	80.10	2.69	10.41	34.5%

\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-04 - XBS.DWG

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File: XGD.met

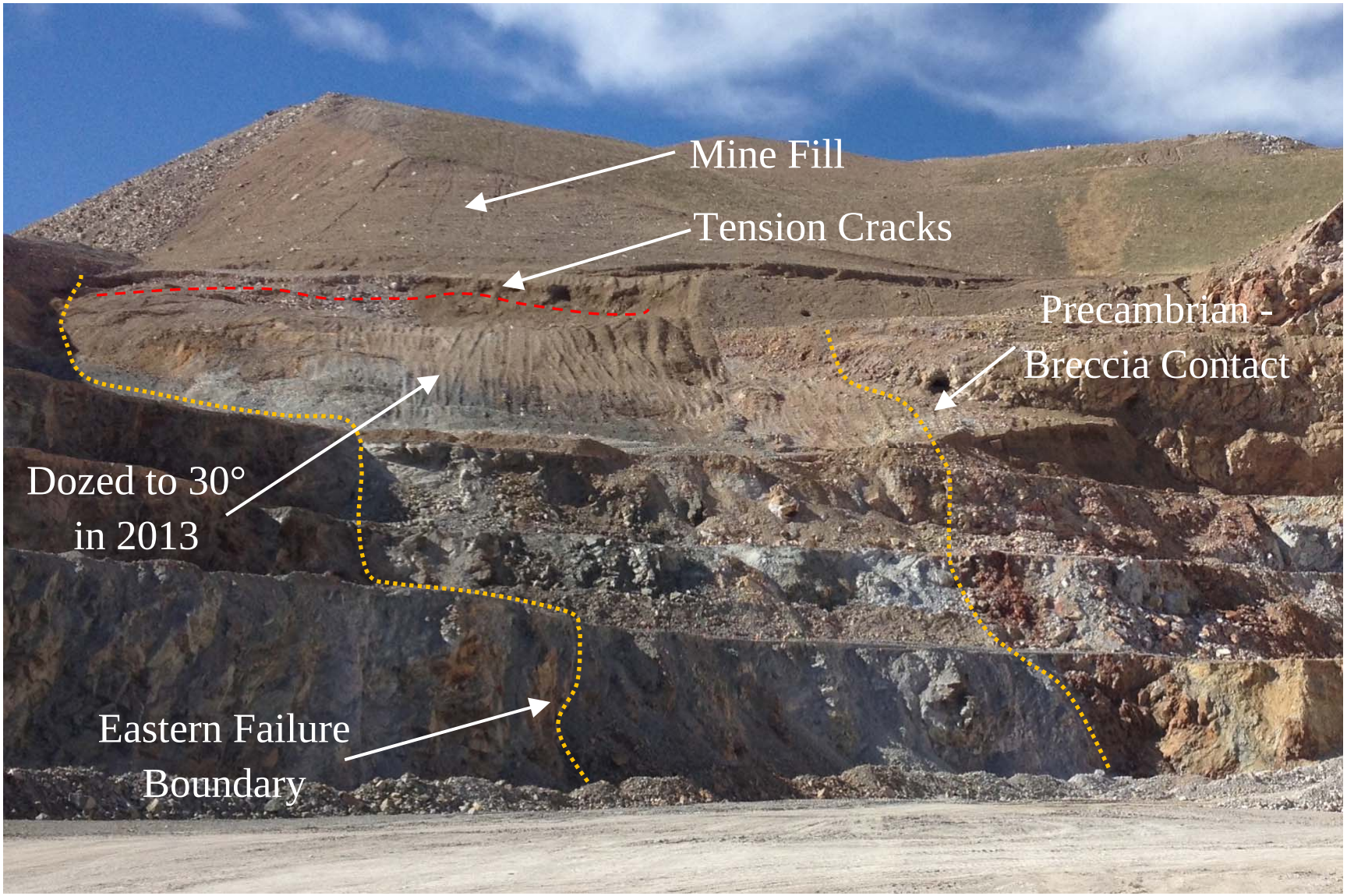
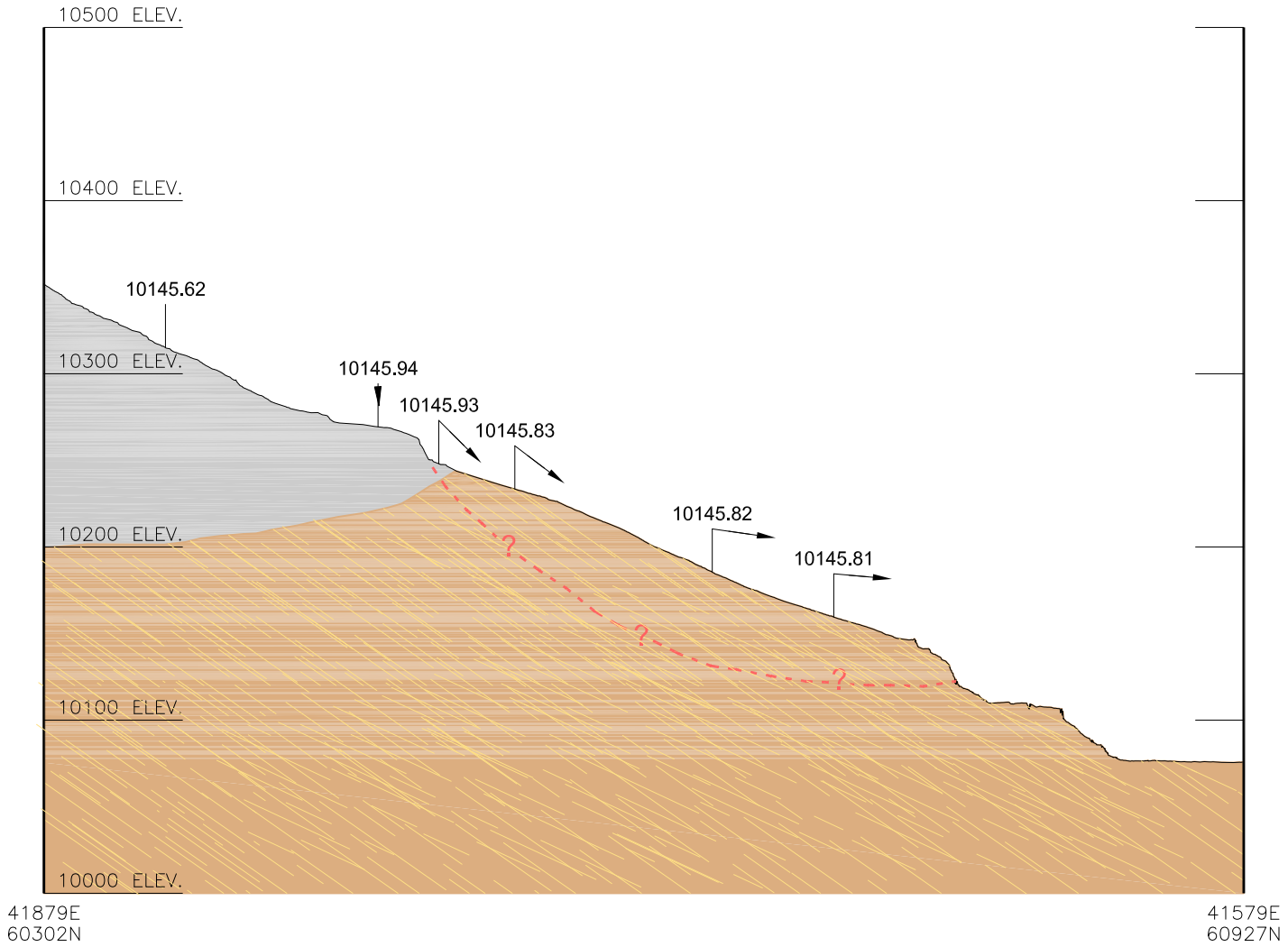


Figure 6-5. Overview Photograph of South WHEX Instability, Taken in June 2014.



Figure 6-6. Photograph of Foliation in the Schist Dipping Towards the North, WHEX Mine, El. 10110



0 50 100
SCALE FEET
(1"=100')

LEGEND

PRECAMBRIAN
DUMP
POTENTIAL SLIP SURFACE
FOLIATION
10145.82
PRISM DISPLACEMENT VECTORS

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\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-07 - PRISM_SECTION.DWG

SOUTH WHEX PRISM VECTORS MARCH 2014 (Looking SW)

CRIPPLE CREEK & VICTOR

SCALE 1"=100'

FIGURE 6-7

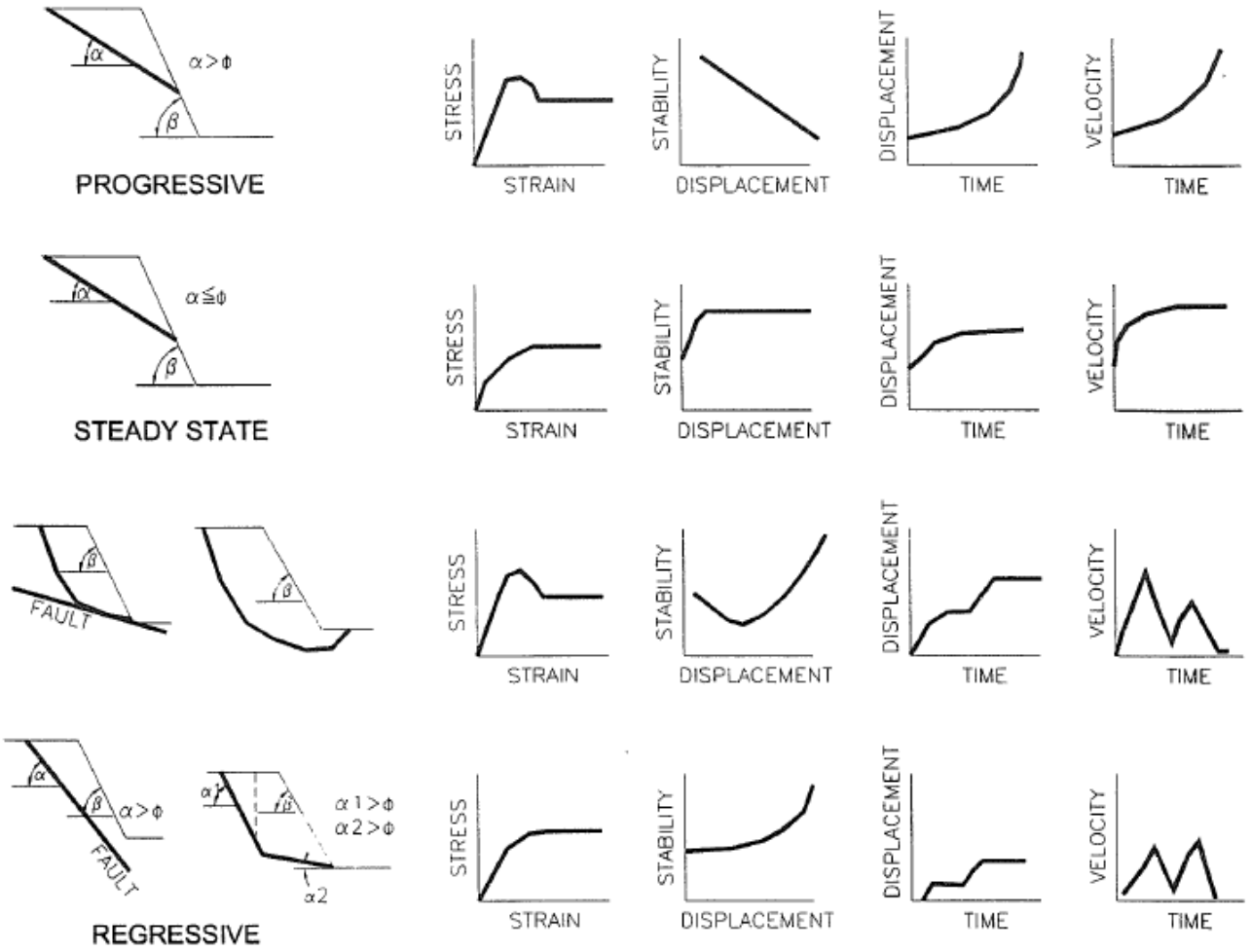


Figure 6-08. Slope Instability Types and their Characteristic Behavior: Progressive, Steady State, and Regressive

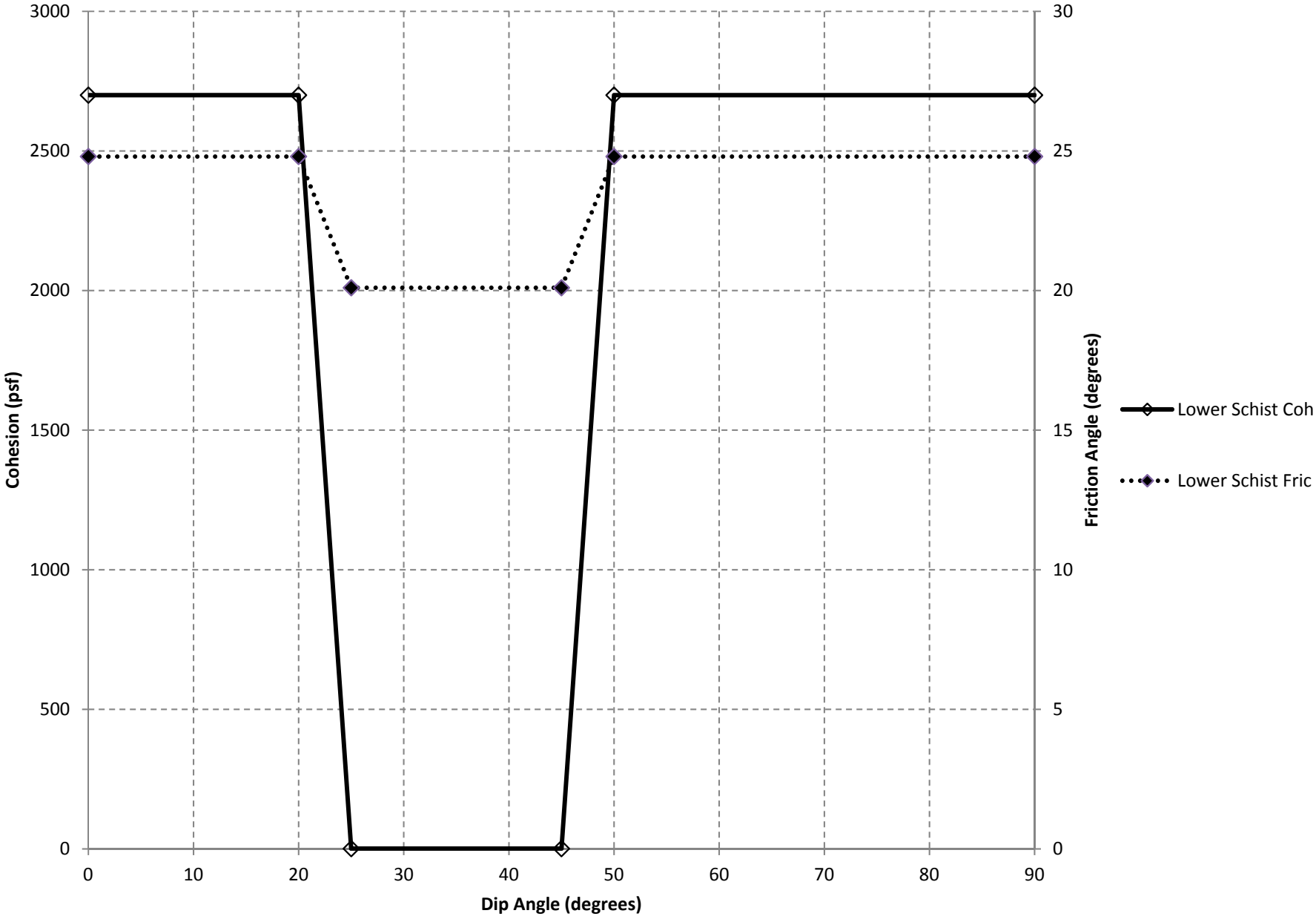


Figure 6-9. Schist Foliation Anisotropic Strengths by Dip Angle

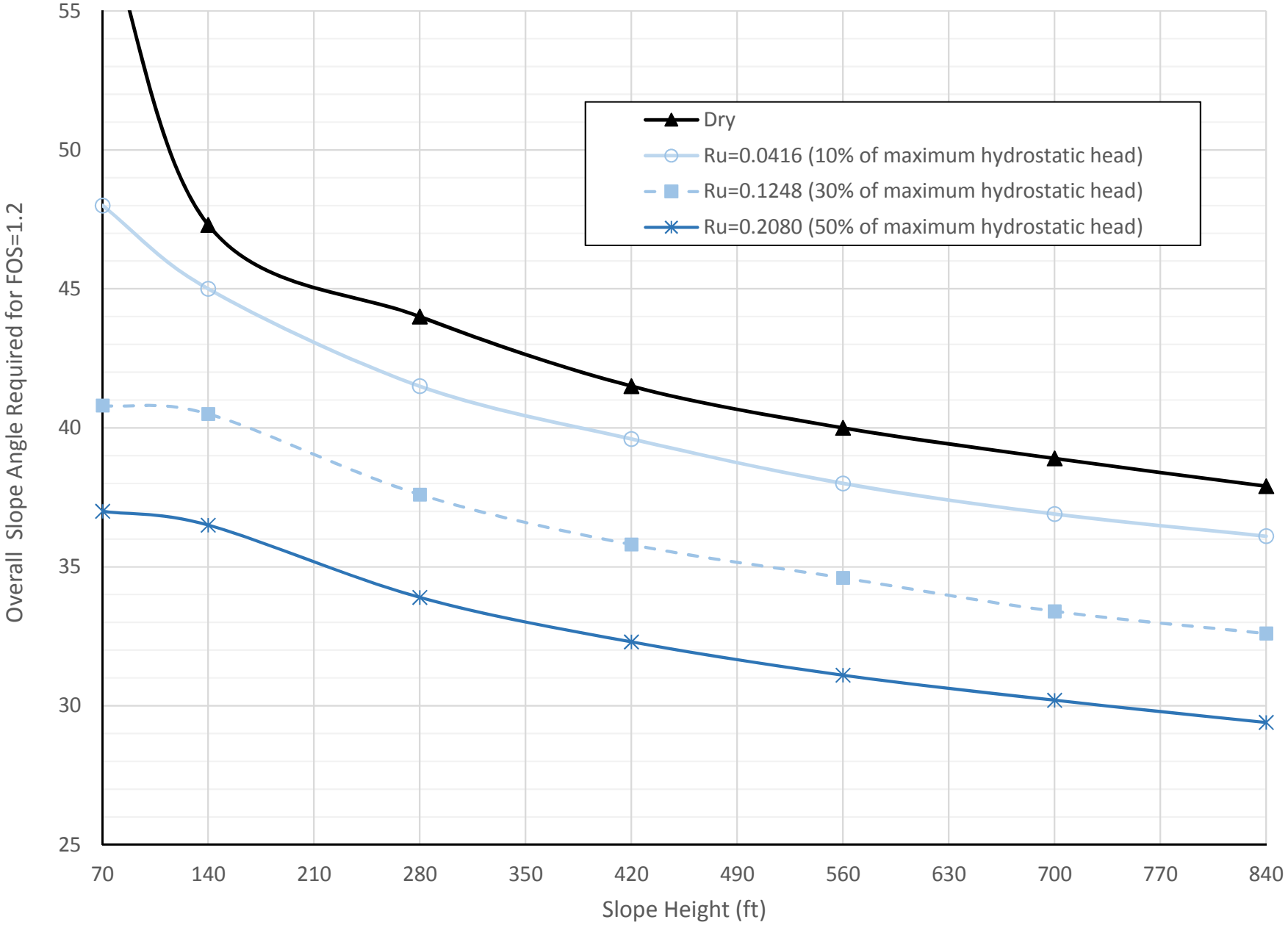
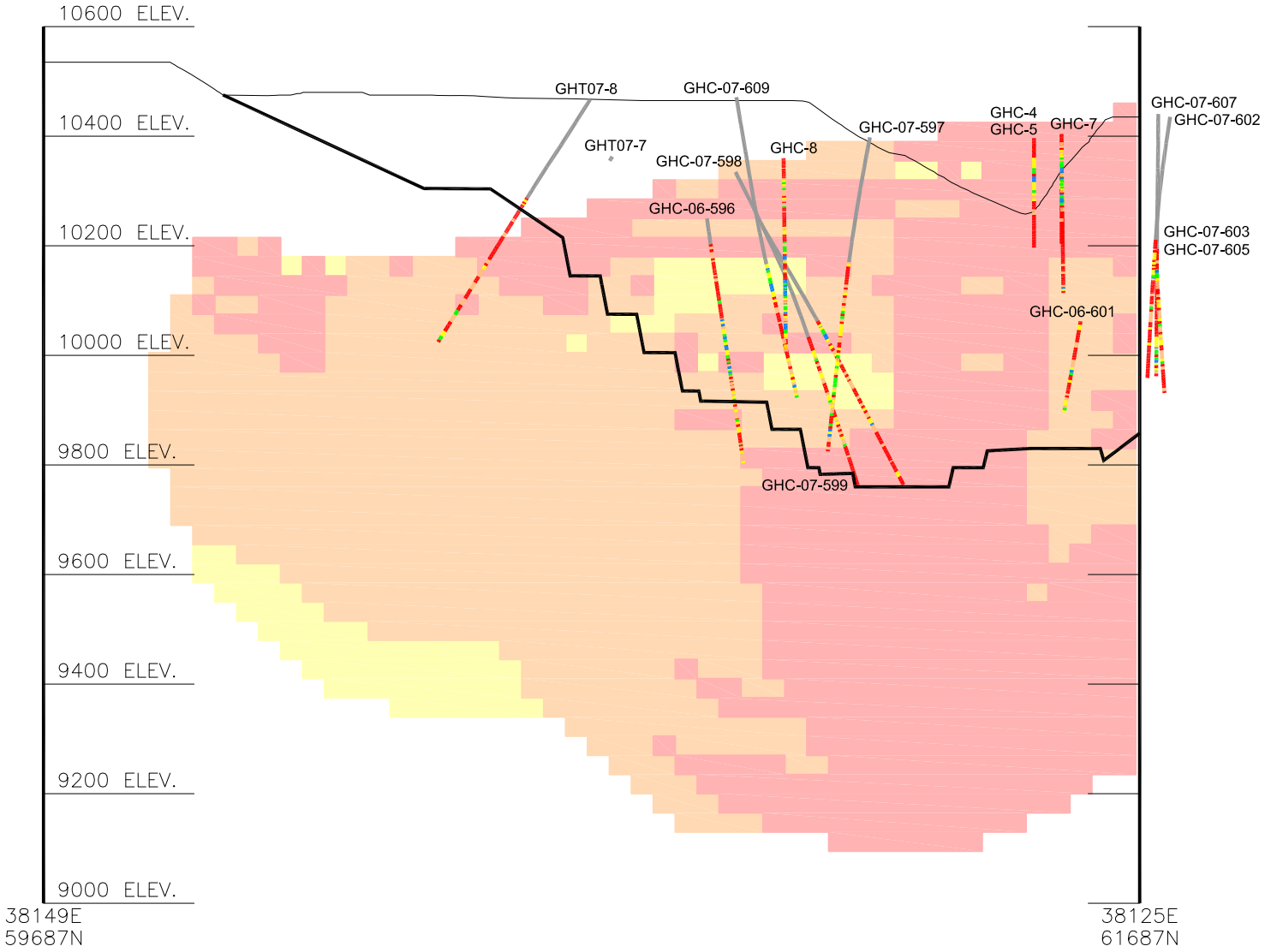


Figure 6-10 Slope Height Versus Overall Slope Angle Required for Factor of Saftey of 1.20 for Slopes Within the Globe Hill Pipe Altered Zone



0 150 300
SCALE FEET
(1"=300')

LEGEND

- BLOCK RQD 0-20
- BLOCK RQD 20-40
- BLOCK RQD 40-60
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN
- HOLE RQD 0-20
- HOLE RQD 20-40
- HOLE RQD 40-60
- HOLE RQD 60-80
- HOLE RQD 80-100
- HOLE NO DATA

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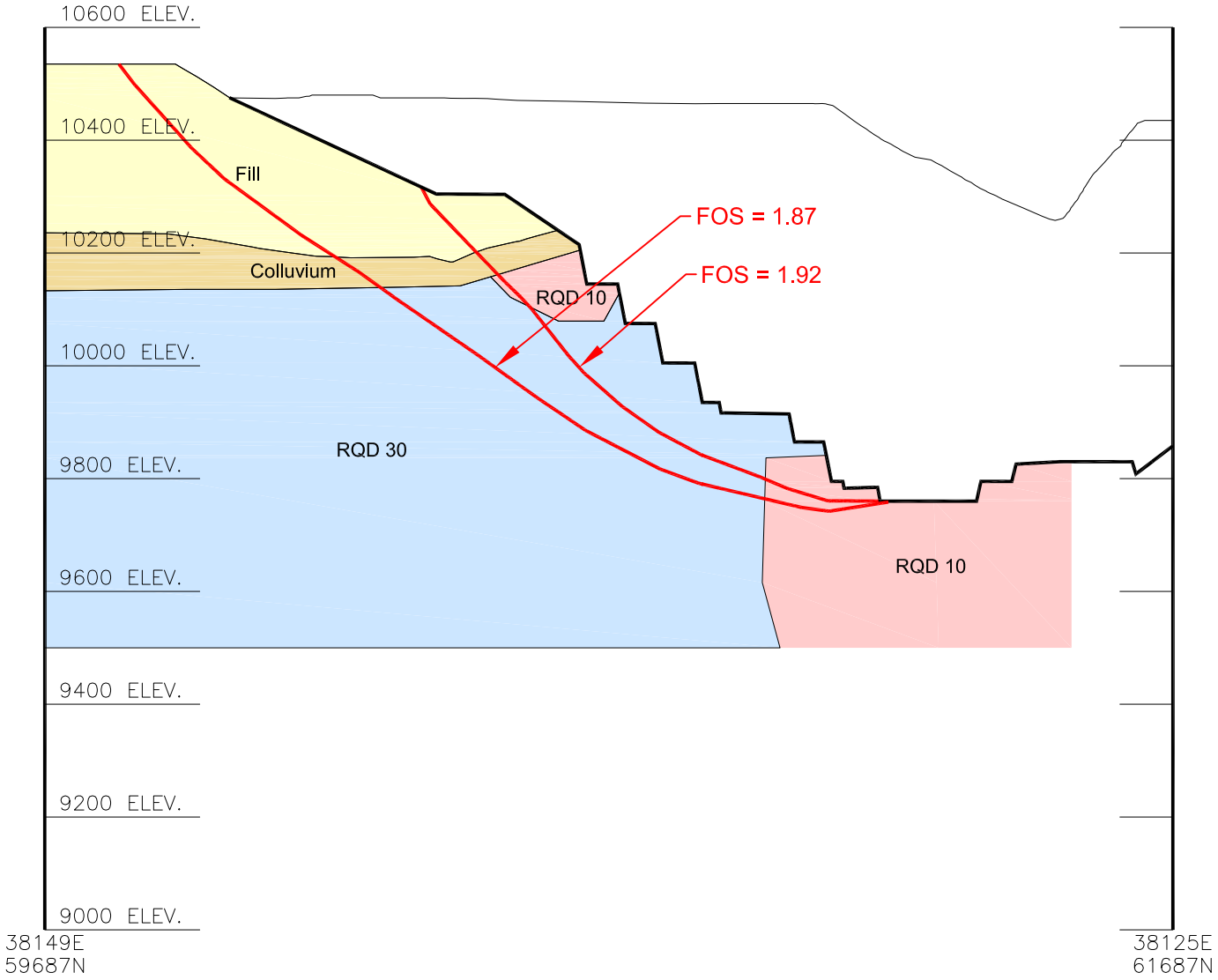
\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-11 - GH-1_RQD_GH-1.DWG

CROSS SECTION GH-1 WITH RQD DATA (Looking West)

CRIPPLE CREEK & VICTOR

SCALE 1"=300'

FIGURE 6-11



0 150 300
SCALE FEET
(1"=300')

LEGEND

- GTRCK 2 PHONOLITE
- GTRCK 5 GLOBE HILL PIPE
- GTRCK 6 COLLUVIUM / WEATHERED
- GTRCK 7 FILL
- MARCH 2011 TOPOGRAPHY
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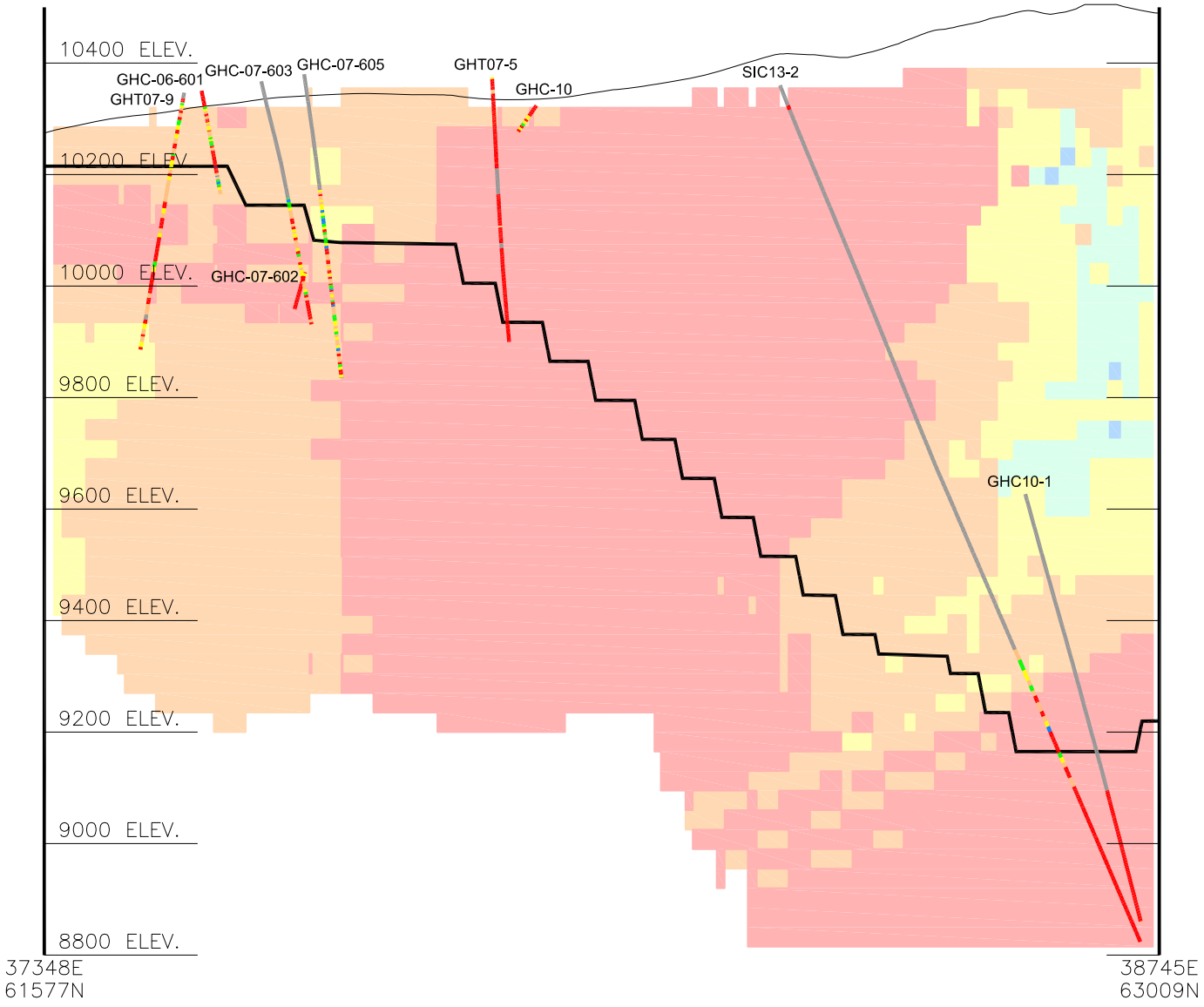
\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-12 - GH-1.DWG

SECTION GH-1 GLOBAL ANALYSIS AND GEOLOGY (Looking West)

CRIPPLE CREEK & VICTOR

SCALE 1"=300'

FIGURE 6-12



SCALE 0 150 300 FEET (1"=300')

LEGEND

- BLOCK RQD 0-20
- BLOCK RQD 20-40
- BLOCK RQD 40-60
- BLOCK RQD 60-80
- BLOCK RQD 80-100
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN
- HOLE RQD 0-20
- HOLE RQD 20-40
- HOLE RQD 40-60
- HOLE RQD 60-80
- HOLE RQD 80-100
- HOLE NO DATA

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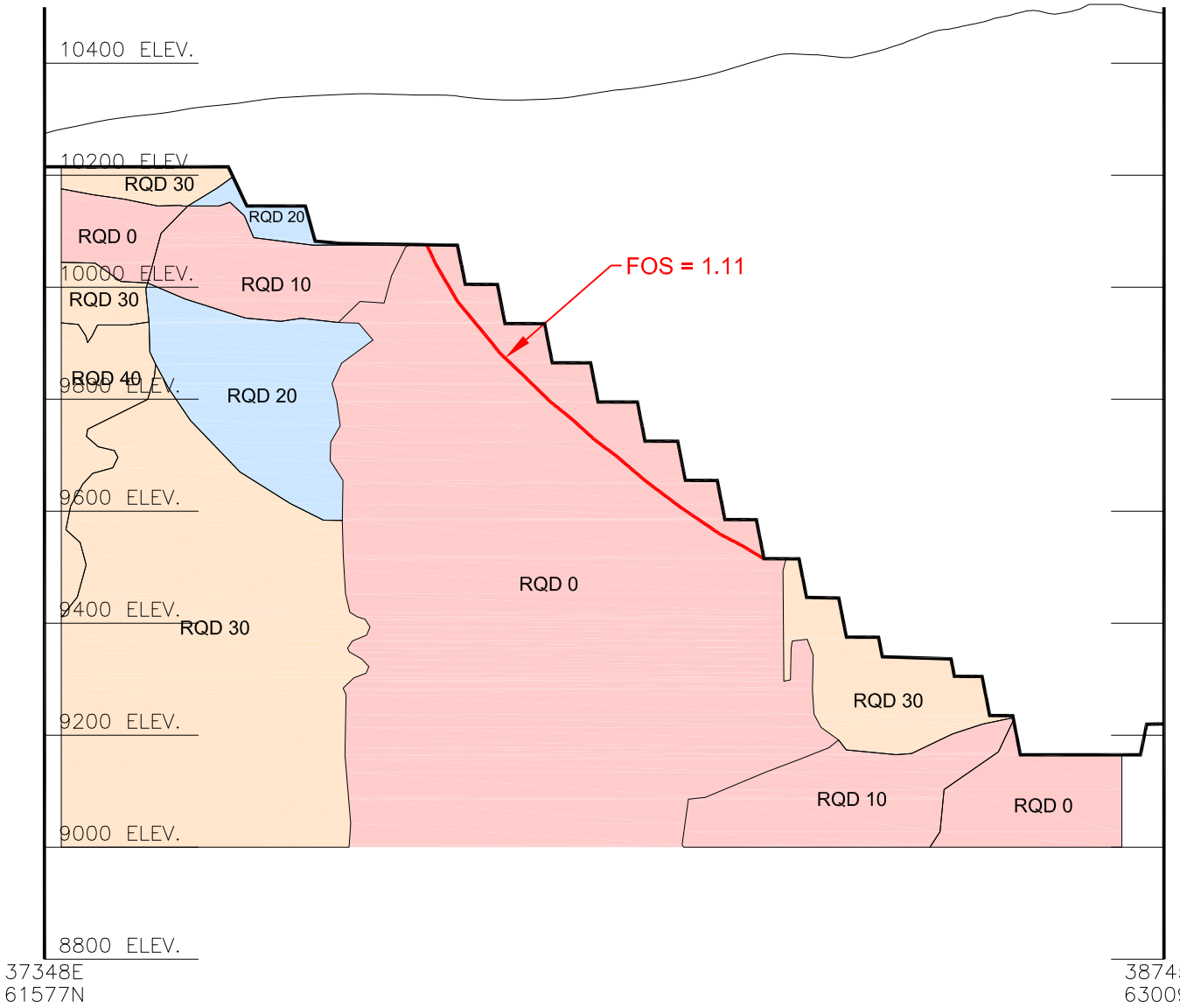
\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-13 - GH-2_RQD_GH-2.DWG

CROSS SECTION GH-2 WITH RQD DATA (Looking NW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300'

FIGURE 6-13



SCALE 0 150 300 FEET (1"=300')

LEGEND

- GTRCK 1 CRIPPLE CREEK BRECCIA
- GTRCK 2 PHONOLITE
- GTRCK 5 GLOBE HILL PIPE
- MARCH 2011 TOPOGRAPHY
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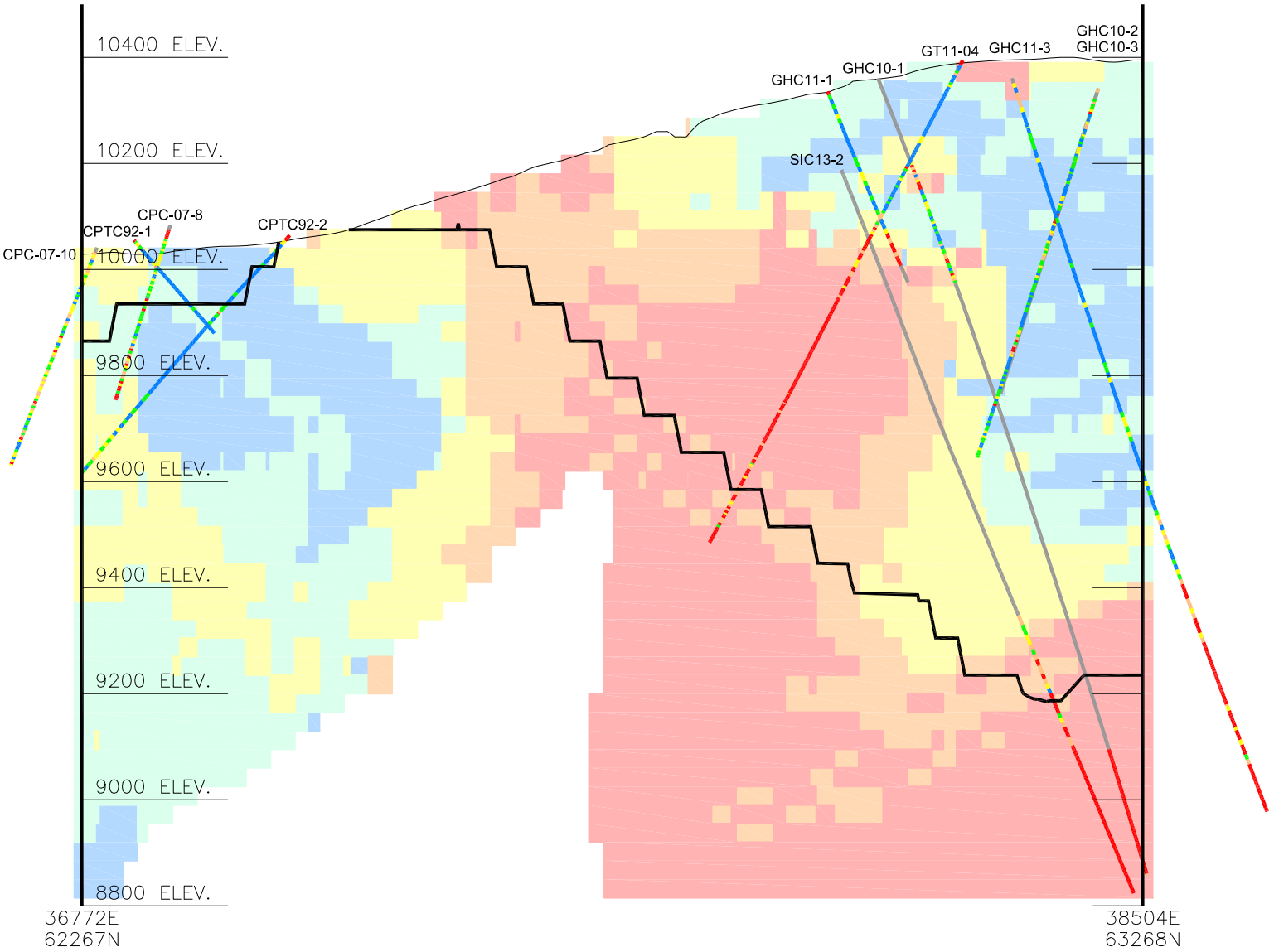
\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-14 - GH-2.DWG

SECTION GH-2 GLOBAL ANALYSIS AND GEOLOGY (Looking NW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300'

FIGURE 6-14



SCALE 0 150 300 FEET (1"=300')

LEGEND

- BLOCK RQD 0-20
- BLOCK RQD 20-40
- BLOCK RQD 40-60
- BLOCK RQD 60-80
- BLOCK RQD 80-100
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN
- HOLE RQD 0-20
- HOLE RQD 20-40
- HOLE RQD 40-60
- HOLE RQD 60-80
- HOLE RQD 80-100
- HOLE NO DATA

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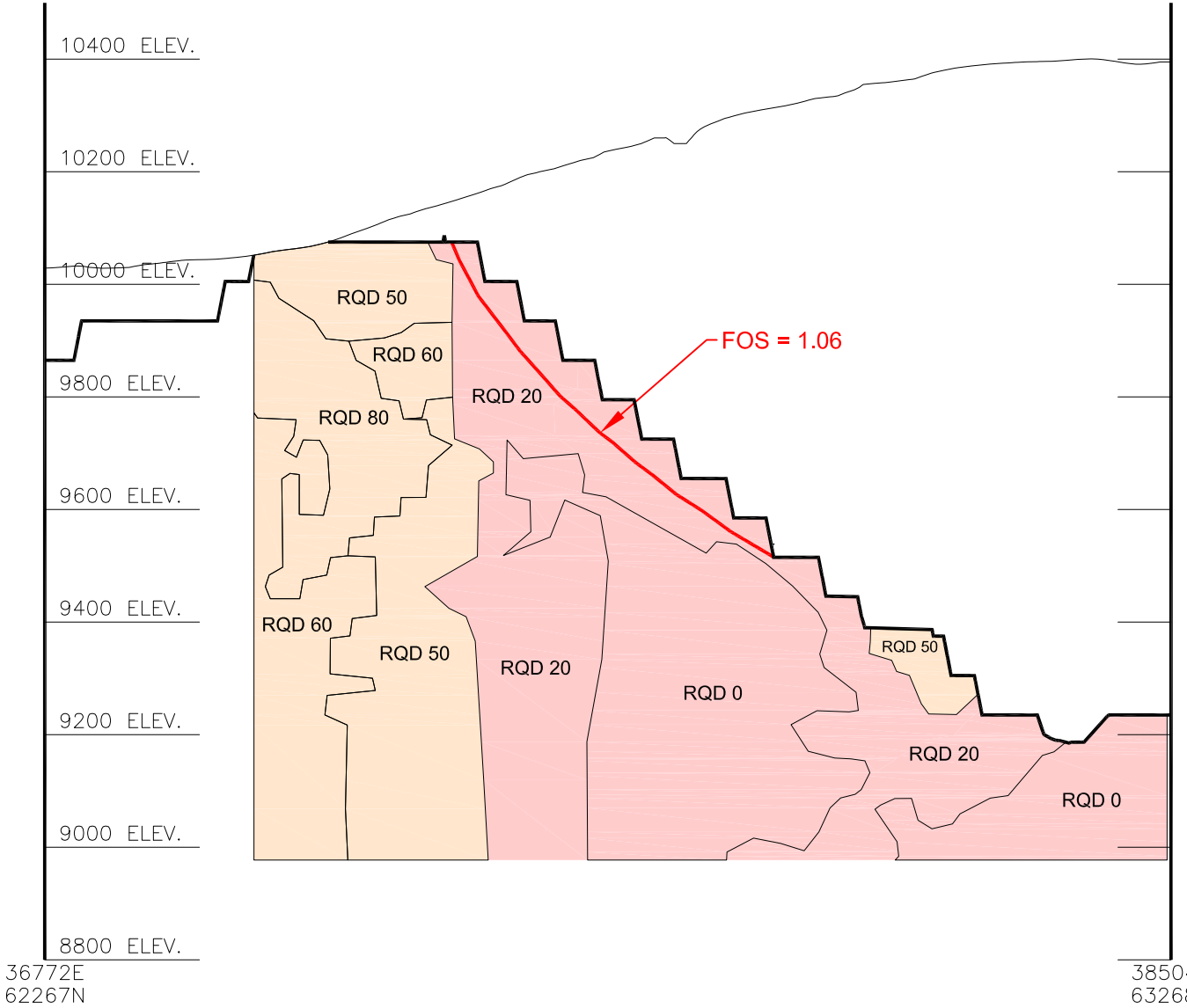
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\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-15 - GH-3_RQD_GH-3.DWG

CROSS SECTION GH-3 WITH RQD DATA (Looking NW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300' | FIGURE 6-15



SCALE 0 150 300 FEET (1"=300')

LEGEND

- GTRCK 1 CRIPPLE CREEK BRECCIA
- GTRCK 5 GLOBE HILL PIPE
- MARCH 2011 TOPOGRAPHY
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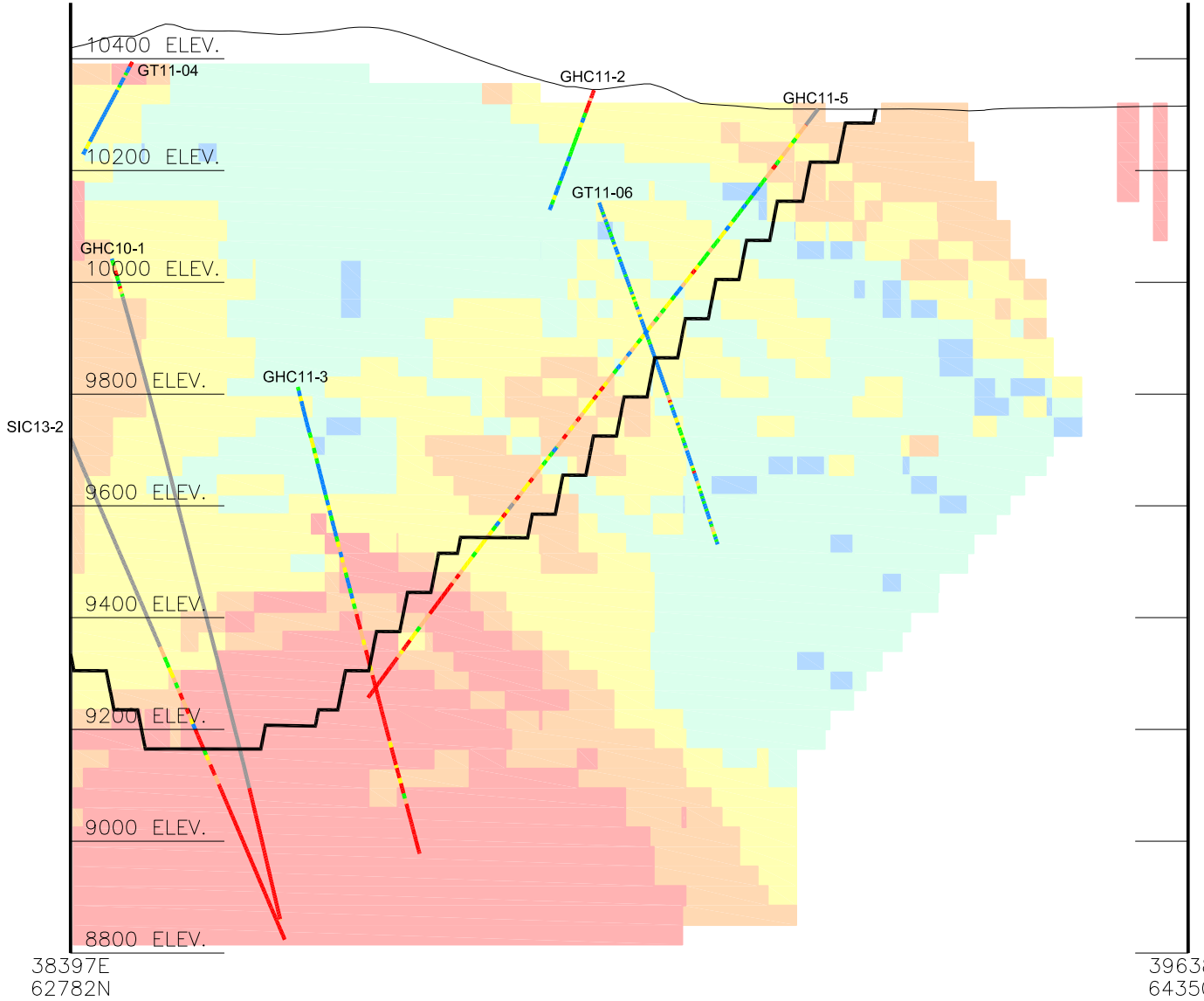
\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-16 - GH-3.DWG

SECTION GH-3 GLOBAL ANALYSIS AND GEOLOGY (Looking NW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300'

FIGURE 6-16



SCALE 0 150 300 FEET (1"=300')

LEGEND

- BLOCK RQD 0-20
- BLOCK RQD 20-40
- BLOCK RQD 40-60
- BLOCK RQD 60-80
- BLOCK RQD 80-100
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN
- HOLE RQD 0-20
- HOLE RQD 20-40
- HOLE RQD 40-60
- HOLE RQD 60-80
- HOLE RQD 80-100
- HOLE NO DATA

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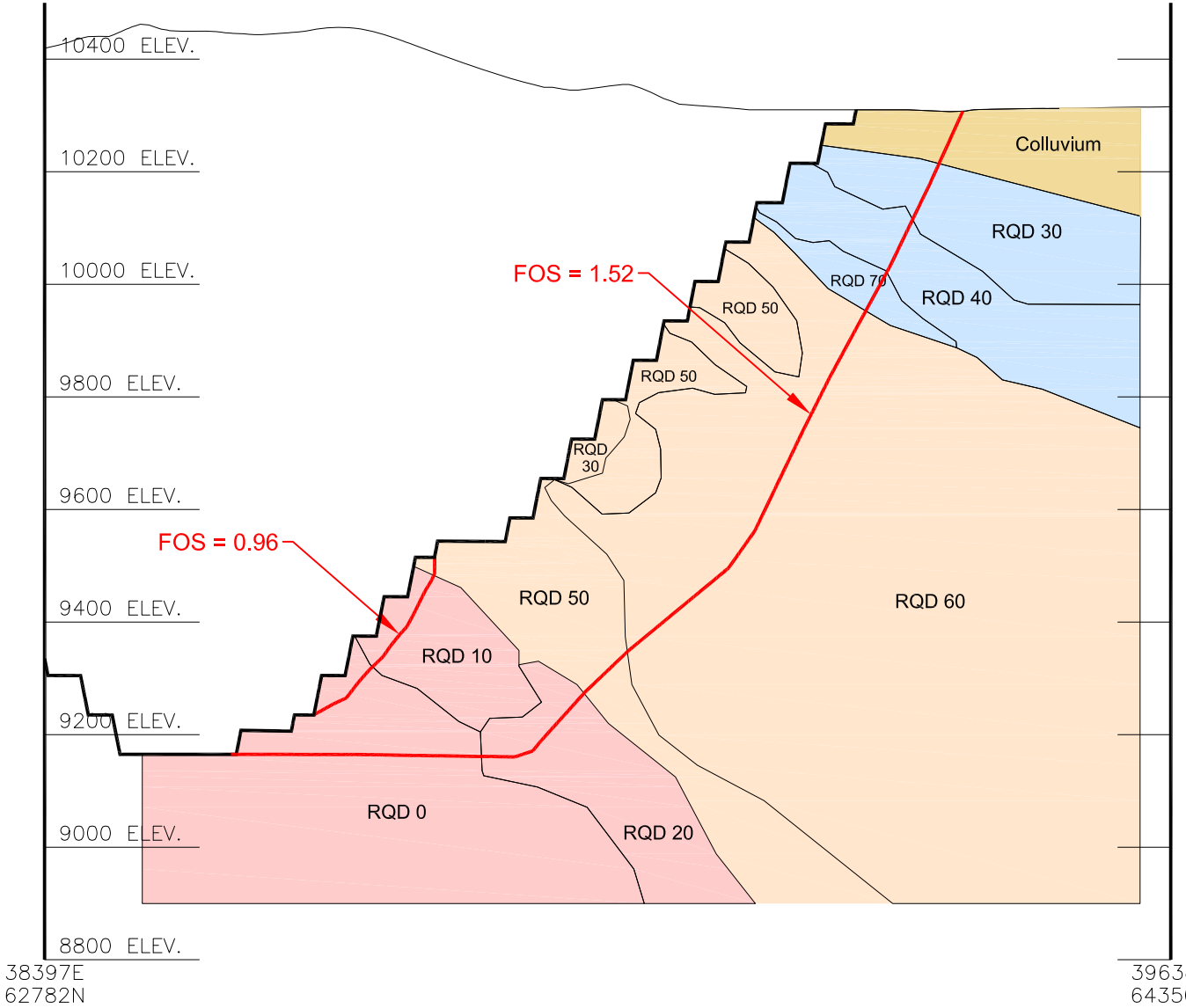
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CROSS SECTION GH-4 WITH RQD DATA (Looking NW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300'

FIGURE 6-17



SCALE 0 150 300 FEET (1"=300')

LEGEND

- GTRCK 1 CRIPPLE CREEK BRECCIA
- GTRCK 2 PHONOLITE
- GTRCK 5 GLOBE HILL PIPE
- GTRCK 6 COLLUVIUM / WEATHERED
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN

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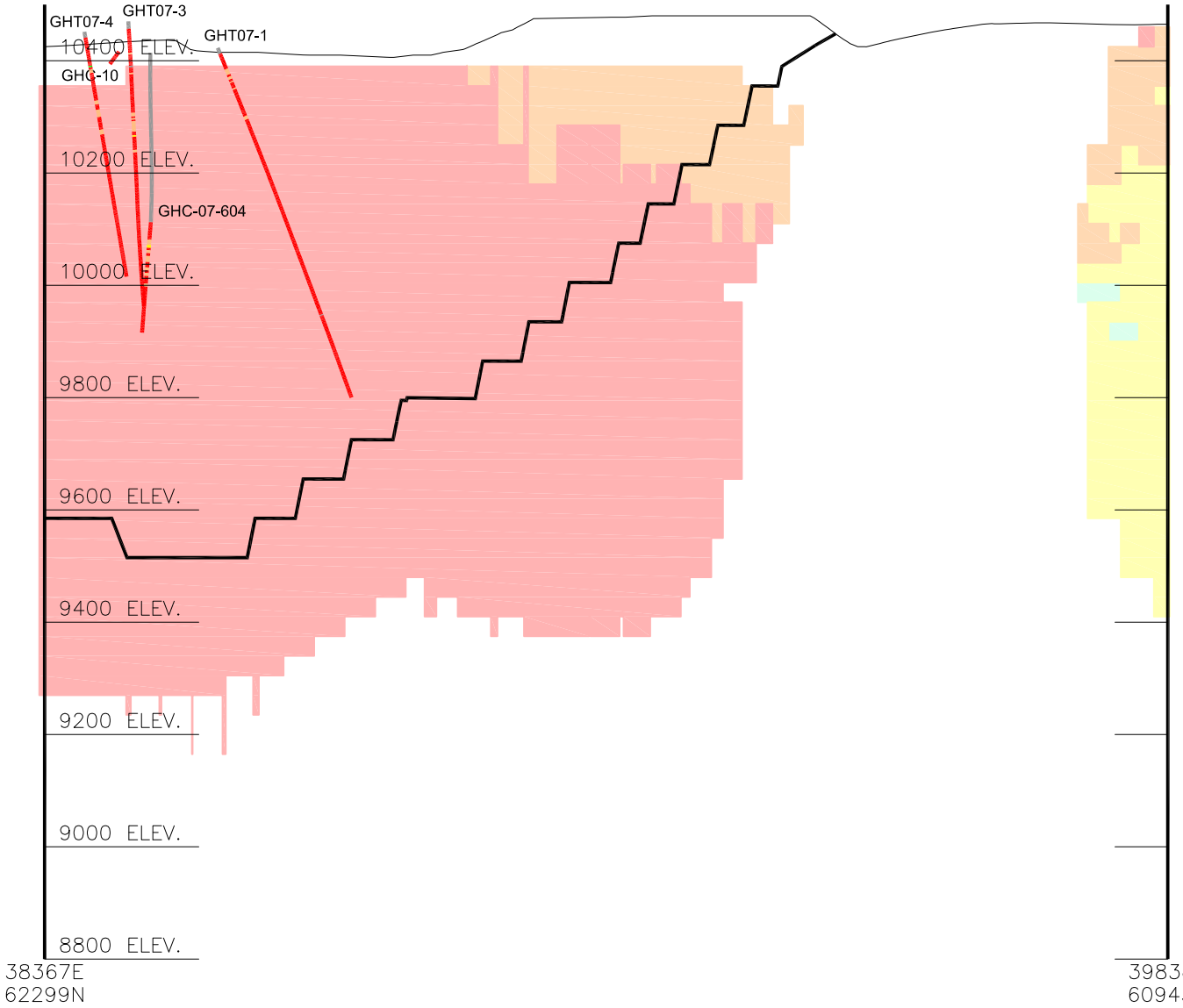
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\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-18 - GH-4.DWG

SECTION GH-4 GLOBAL ANALYSIS AND GEOLOGY (Looking NW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300' | FIGURE 6-18



SCALE 0 150 300 FEET
(1"=300')

LEGEND

- BLOCK RQD 0-20
- BLOCK RQD 20-40
- BLOCK RQD 40-60
- BLOCK RQD 60-80
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN
- HOLE RQD 0-20
- HOLE RQD 20-40
- HOLE RQD 40-60
- HOLE RQD 60-80
- HOLE NO DATA

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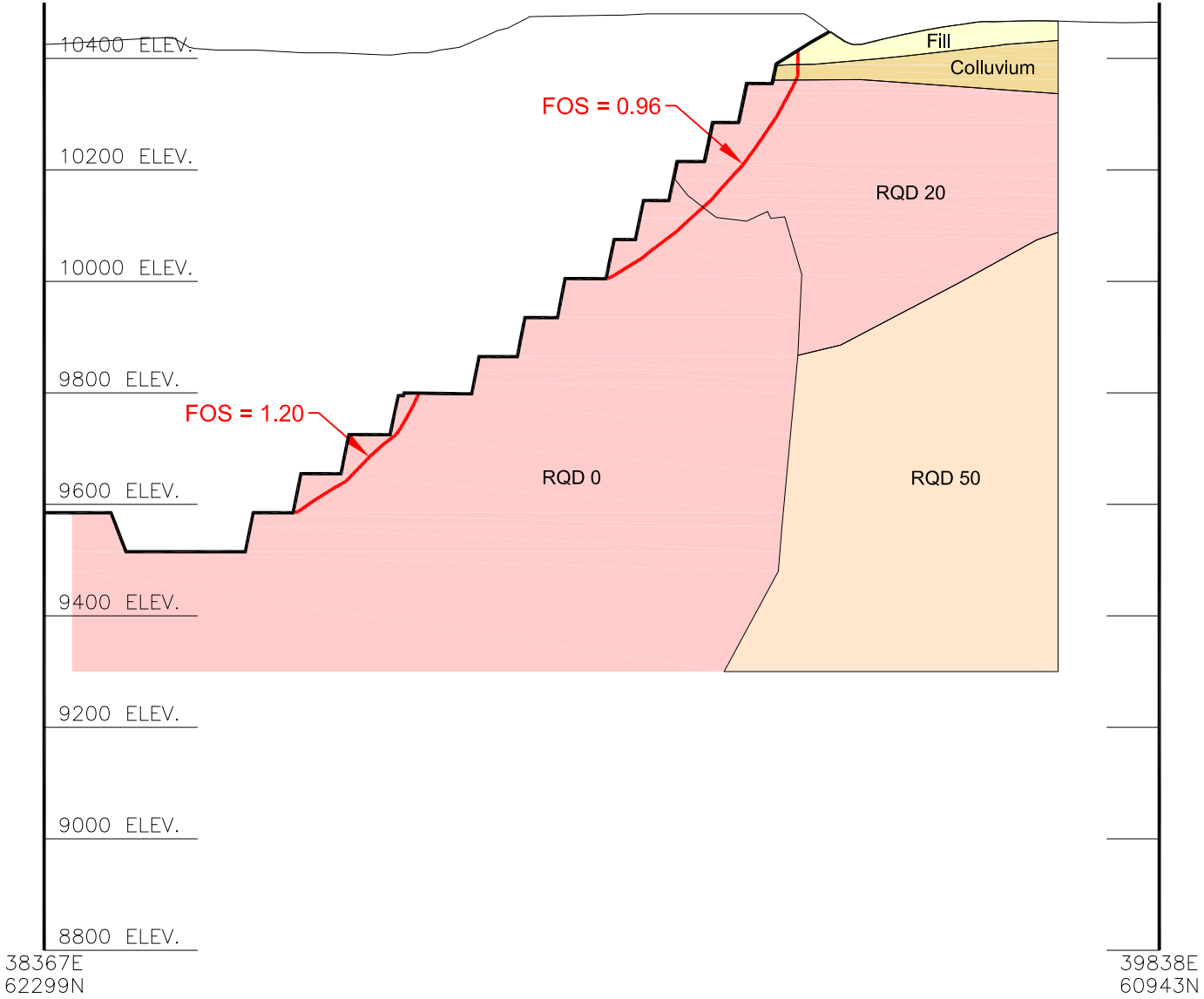
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CROSS SECTION GH-5 WITH RQD DATA (Looking NE)

CRIPPLE CREEK & VICTOR

SCALE 1"=300'

FIGURE 6-19



SCALE 0 150 300 FEET (1"=300')

LEGEND

- GTRCK 1 CRIPPLE CREEK BRECCIA
- GTRCK 5 GLOBE HILL PIPE
- GTRCK 6 COLLUVIUM / WEATHERED
- GTRCK 7 FILL
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN

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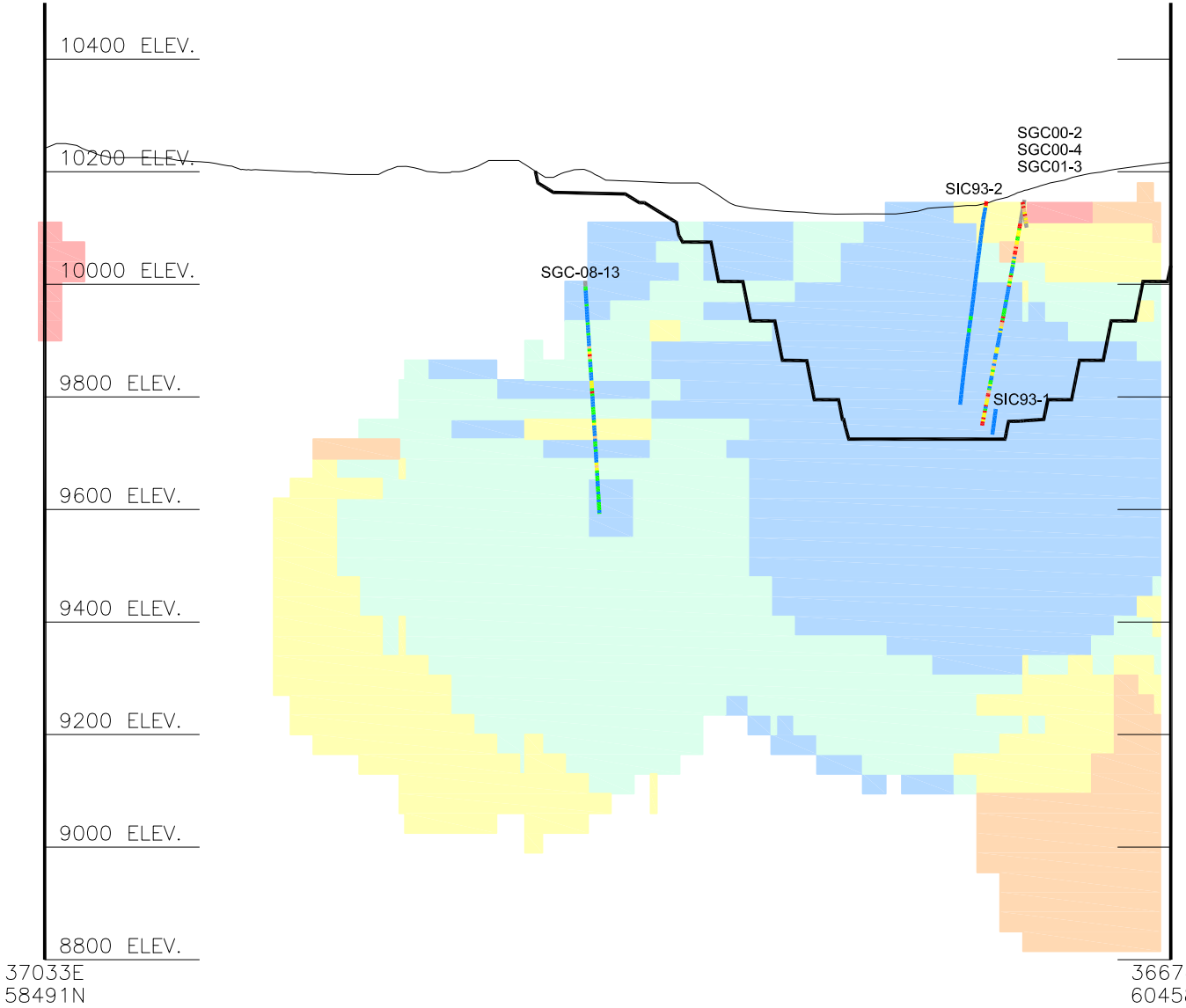
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\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-20 - GH-5.DWG

SECTION GH-5 GLOBAL ANALYSIS AND GEOLOGY (Looking NE)

CRIPPLE CREEK & VICTOR

SCALE 1"=300' | FIGURE 6-20



SCALE 0 150 300 FEET
(1"=300')

LEGEND

- BLOCK RQD 0-20
- BLOCK RQD 20-40
- BLOCK RQD 40-60
- BLOCK RQD 60-80
- BLOCK RQD 80-100
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN
- HOLE RQD 0-20
- HOLE RQD 20-40
- HOLE RQD 40-60
- HOLE RQD 60-80
- HOLE RQD 80-100
- HOLE NO DATA

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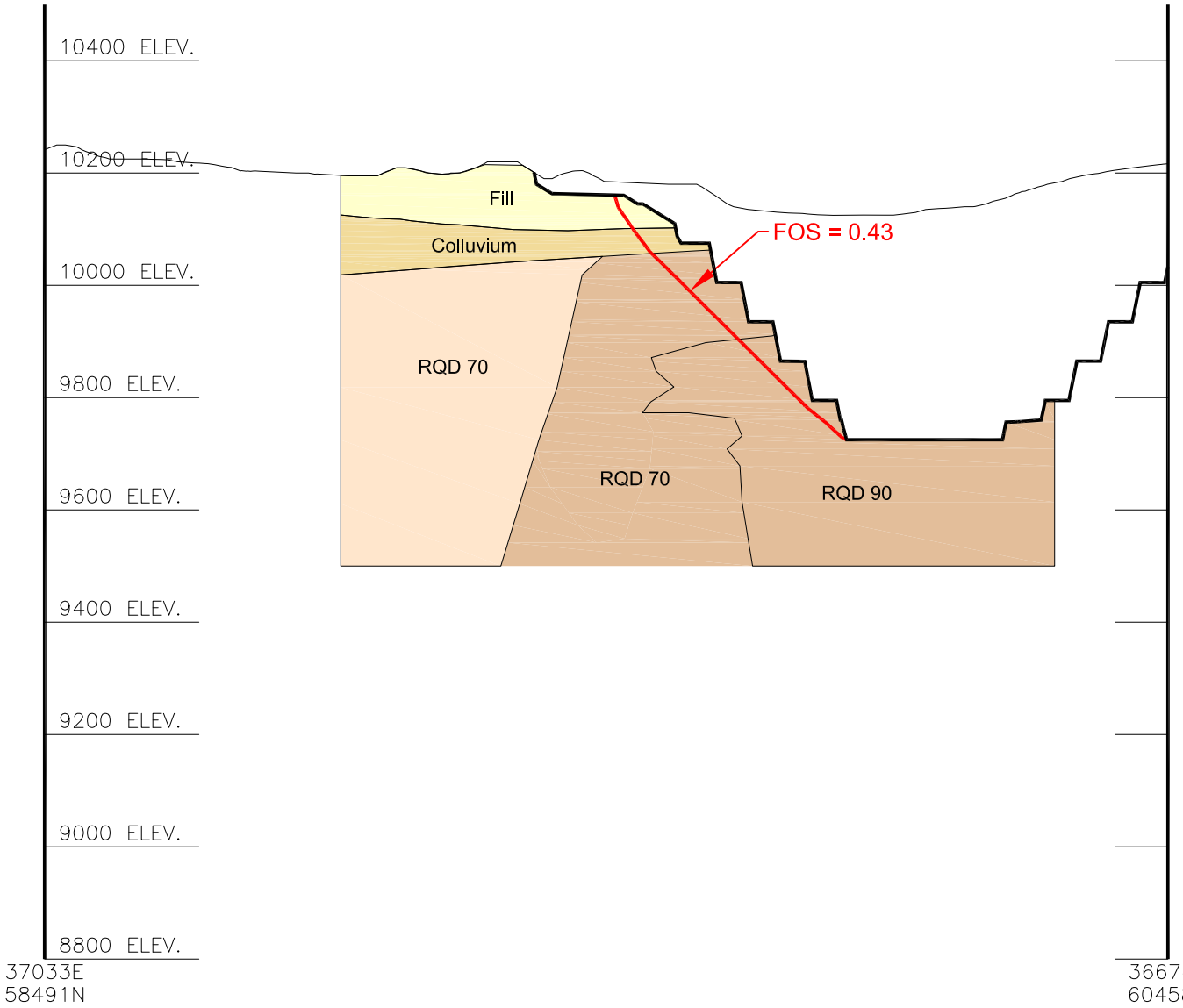
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\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-21 - SI-1_RQD_SI-1.DWG

CROSS SECTION SI-1 WITH RQD DATA (Looking SW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300' | FIGURE 6-21



SCALE 0 150 300 FEET
(1"=300')

LEGEND

- GTRCK 1 CRIPPLE CREEK BRECCIA
- GTRCK 4 PRECAMBRIAN
- GTRCK 6 COLLUVIUM / WEATHERED
- GTRCK 7 FILL
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN

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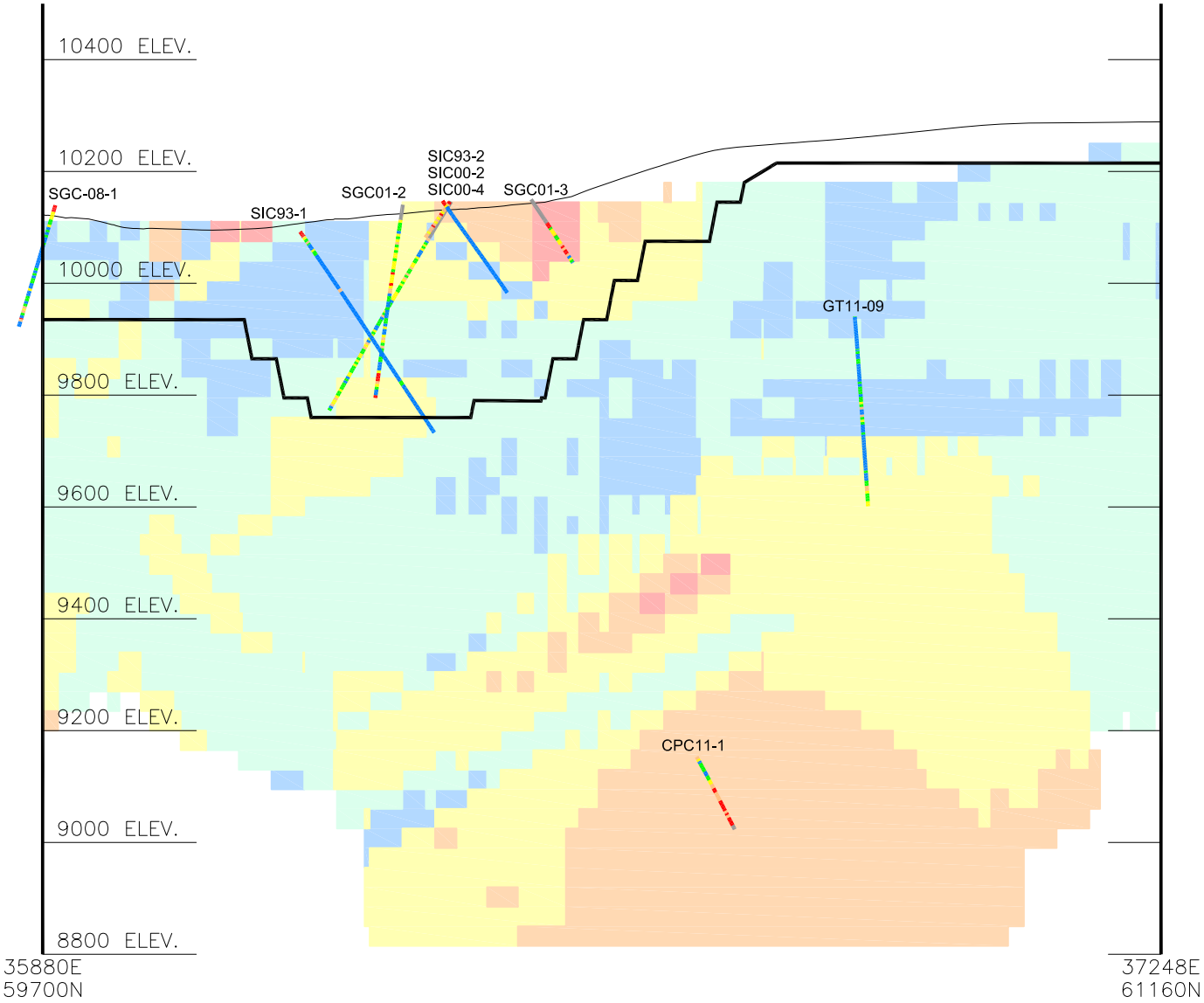
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\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-22 – SI-1.DWG

SECTION SI-1 GLOBAL ANALYSIS AND GEOLOGY (Looking SW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300' | FIGURE 6-22



SCALE 0 150 300 FEET (1"=300')

LEGEND

- BLOCK RQD 0-20
- BLOCK RQD 20-40
- BLOCK RQD 40-60
- BLOCK RQD 60-80
- BLOCK RQD 80-100
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN
- HOLE RQD 0-20
- HOLE RQD 20-40
- HOLE RQD 40-60
- HOLE RQD 60-80
- HOLE RQD 80-100
- HOLE NO DATA

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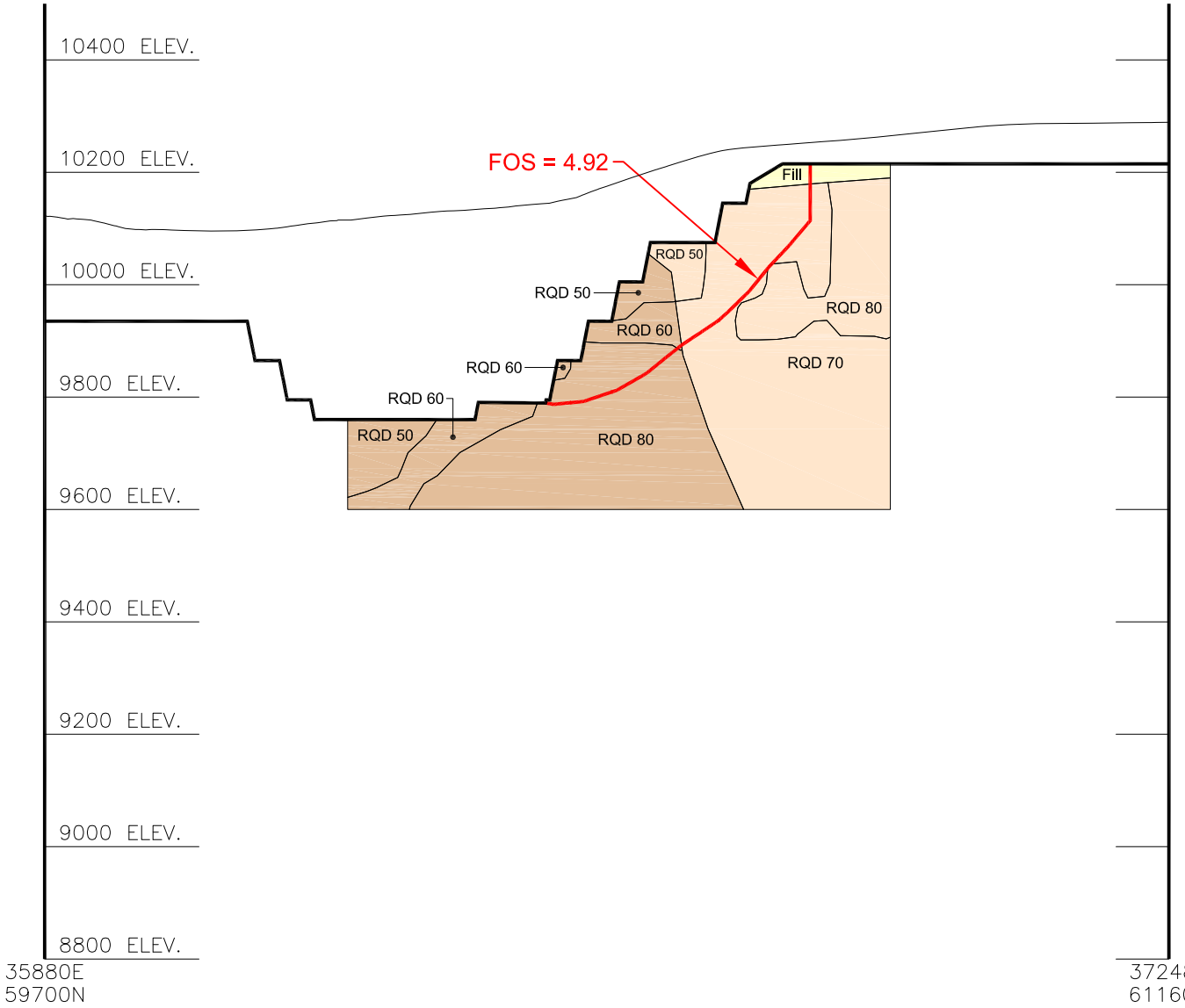
\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-23 – SI-2_RQD_SI-2.DWG

CROSS SECTION SI-2 WITH RQD DATA (Looking NW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300'

FIGURE 6-23



SCALE 0 150 300 FEET (1"=300')

LEGEND

- GTRCK 1 CRIPPLE CREEK BRECCIA
- GTRCK 4 PRECAMBRIAN
- GTRCK 7 FILL
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN

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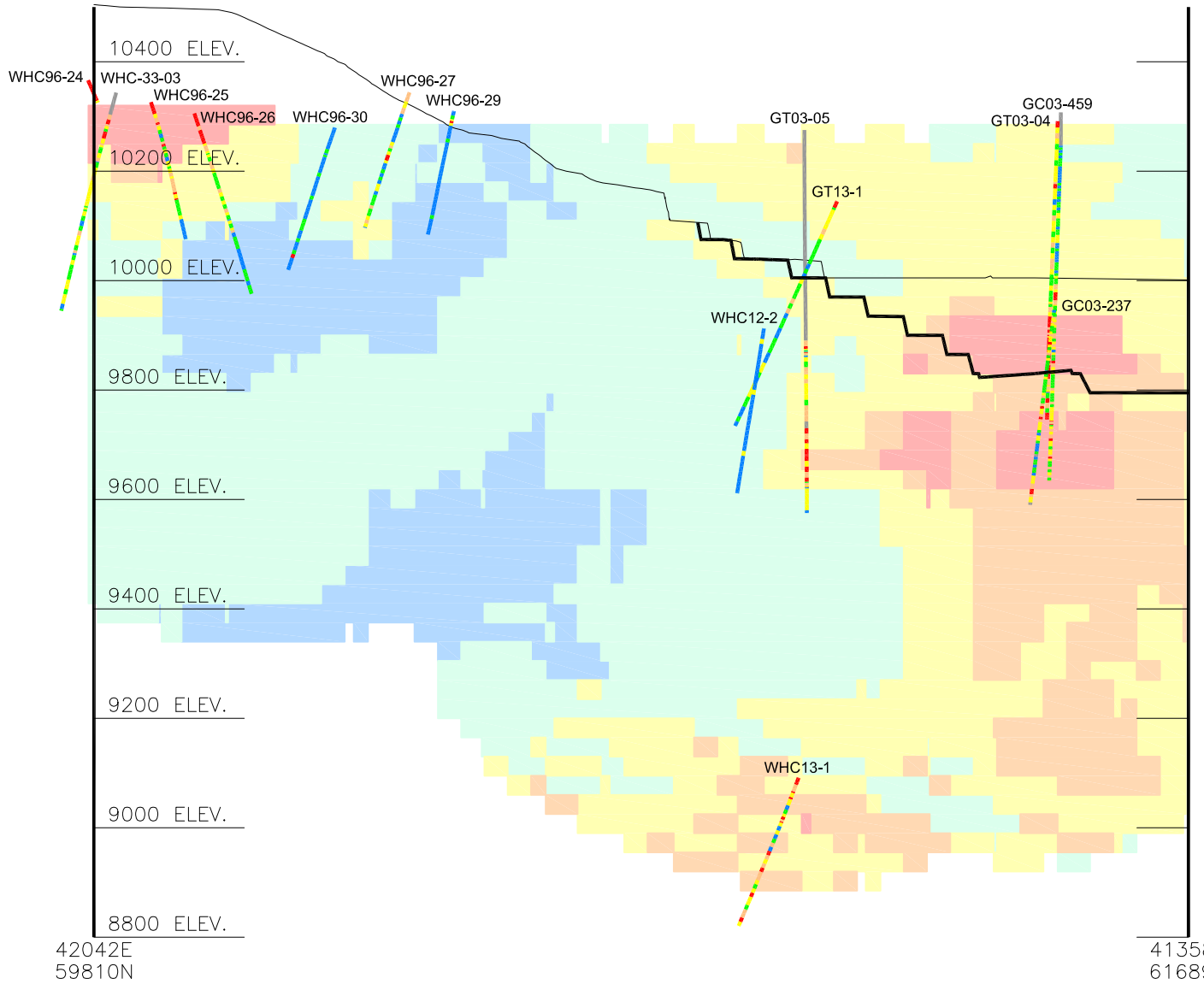
\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-24 – SI-2.DWG

SECTION SI-2 GLOBAL ANALYSIS AND GEOLOGY (Looking NW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300'

FIGURE 6-24



SCALE 0 150 300 FEET (1"=300')

LEGEND

- BLOCK RQD 0-20
- BLOCK RQD 20-40
- BLOCK RQD 40-60
- BLOCK RQD 60-80
- BLOCK RQD 80-100
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN
- HOLE RQD 0-20
- HOLE RQD 20-40
- HOLE RQD 40-60
- HOLE RQD 60-80
- HOLE RQD 80-100
- HOLE NO DATA

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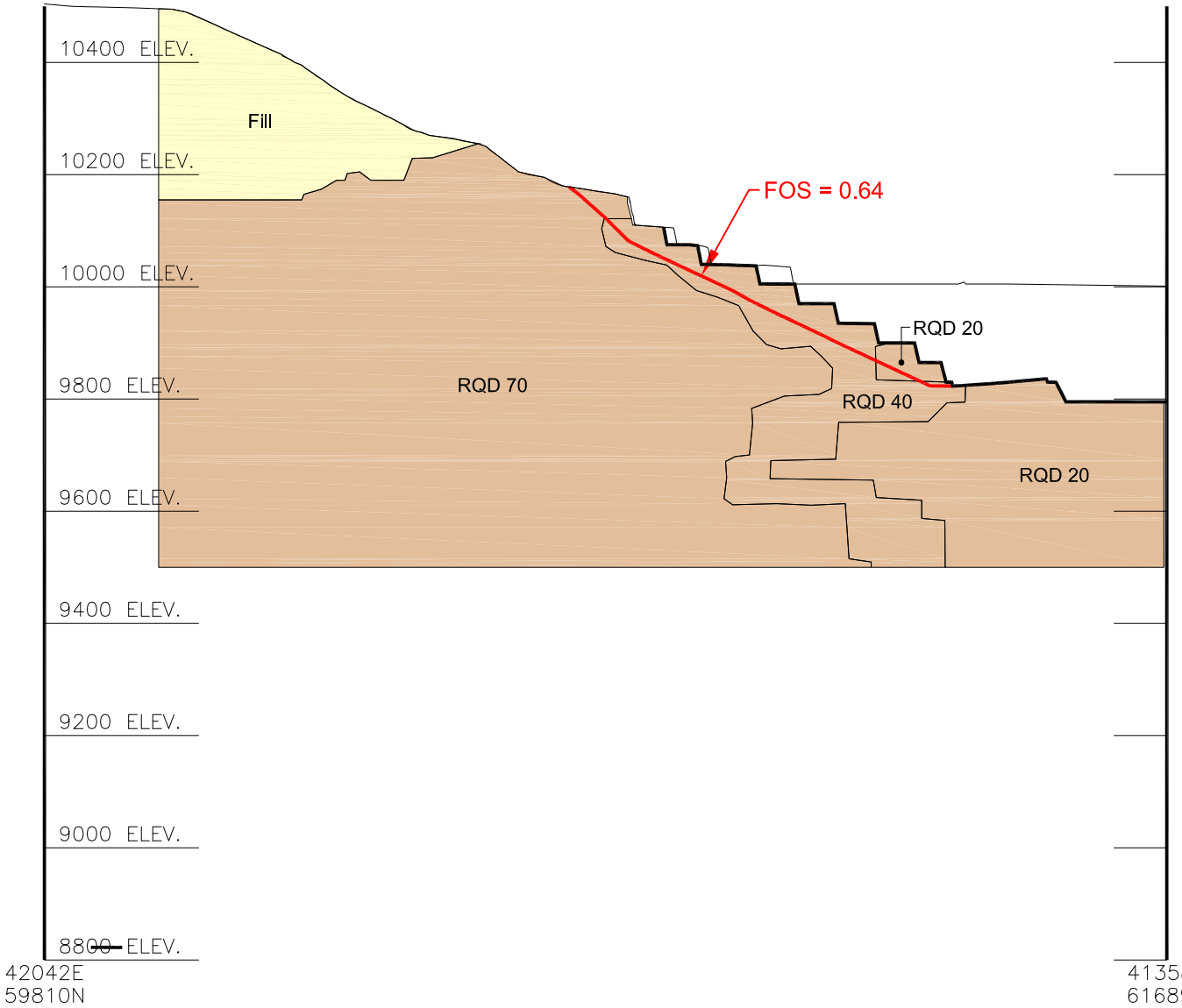
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\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-25 - WH-1_RQD_WH-1.DWG

CROSS SECTION WH-1 WITH RQD DATA (Looking SW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300' | FIGURE 6-25



SCALE 0 150 300 FEET (1"=300')

LEGEND

- GTRCK 4 PRECAMBRIAN
- GTRCK 7 FILL
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN

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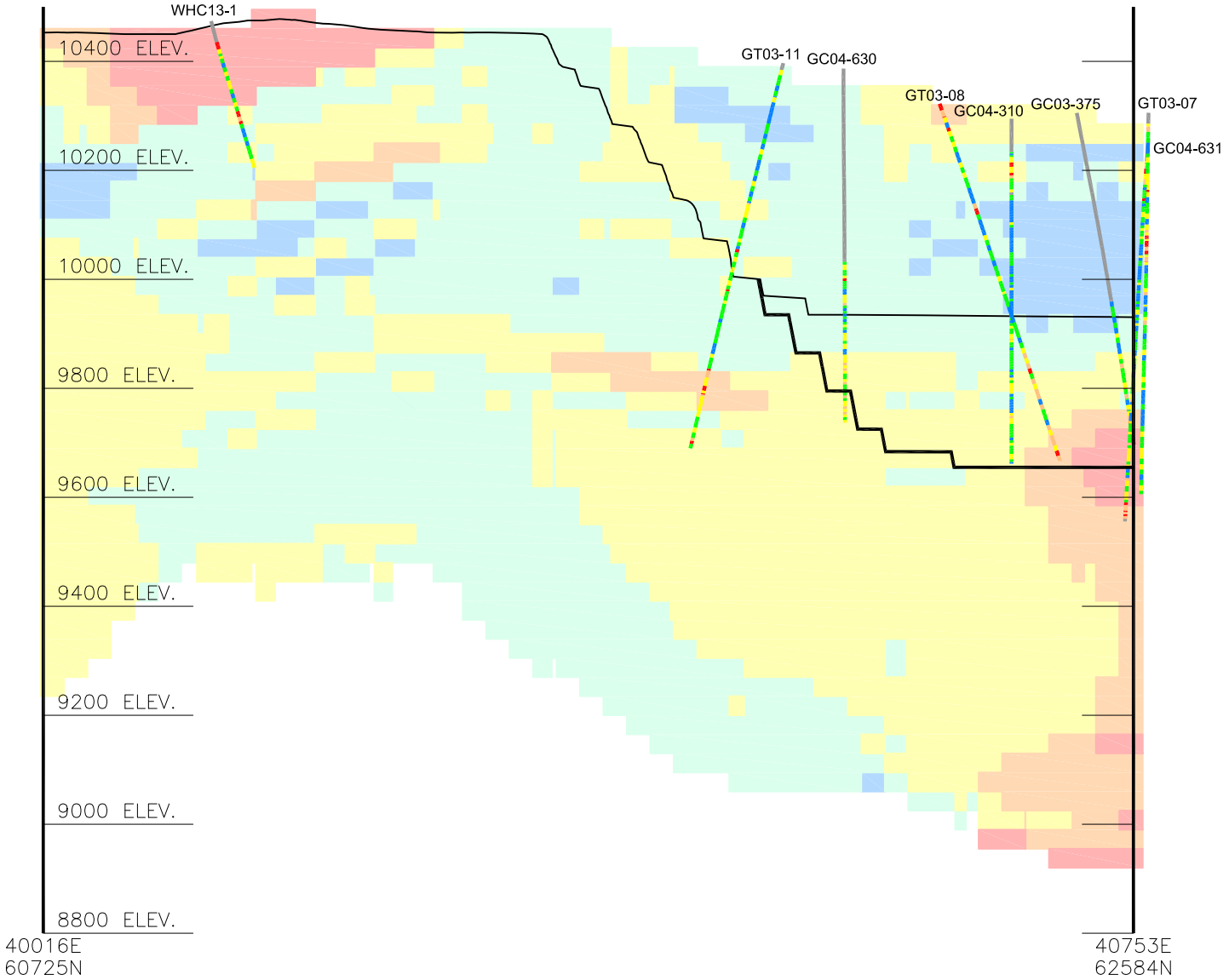
\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-26 – WH-1.DWG

SECTION WH-1 GLOBAL ANALYSIS AND GEOLOGY (Looking SW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300'

FIGURE 6-26



SCALE 0 150 300 FEET
(1"=300')

LEGEND

- BLOCK RQD 0-20
- BLOCK RQD 20-40
- BLOCK RQD 40-60
- BLOCK RQD 60-80
- BLOCK RQD 80-100
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN
- HOLE RQD 0-20
- HOLE RQD 20-40
- HOLE RQD 40-60
- HOLE RQD 60-80
- HOLE RQD 80-100
- HOLE NO DATA

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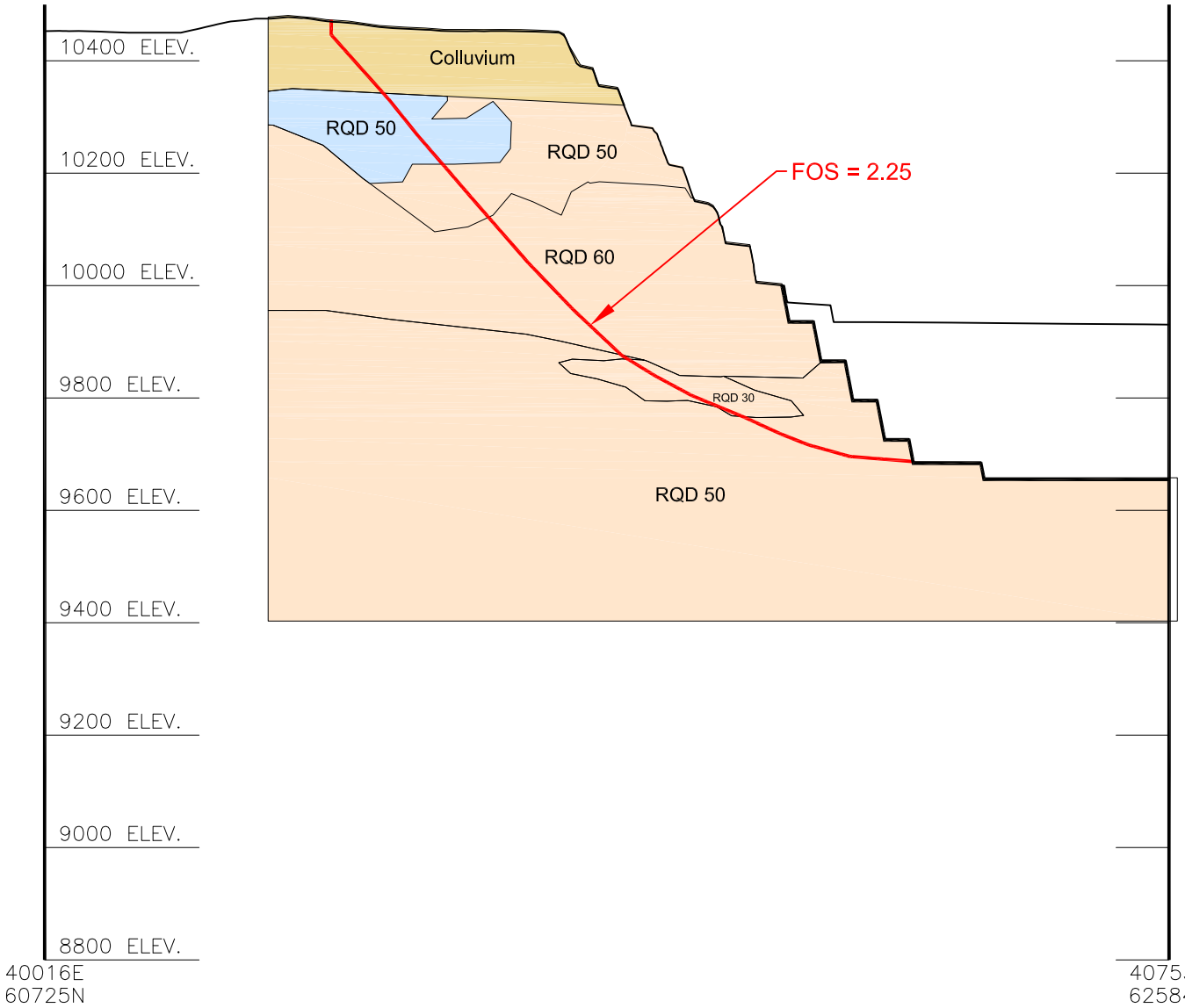
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\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-27 - WH-2_RQD_WH-2.DWG

CROSS SECTION WH-2 WITH RQD DATA (Looking NW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300' | FIGURE 6-27



SCALE 0 150 300 FEET (1"=300')

LEGEND

- GTRCK 1 CRIPPLE CREEK BRECCIA
- GTRCK 2 PHONOLITE
- GTRCK 6 COLLUVIUM / WEATHERED
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN

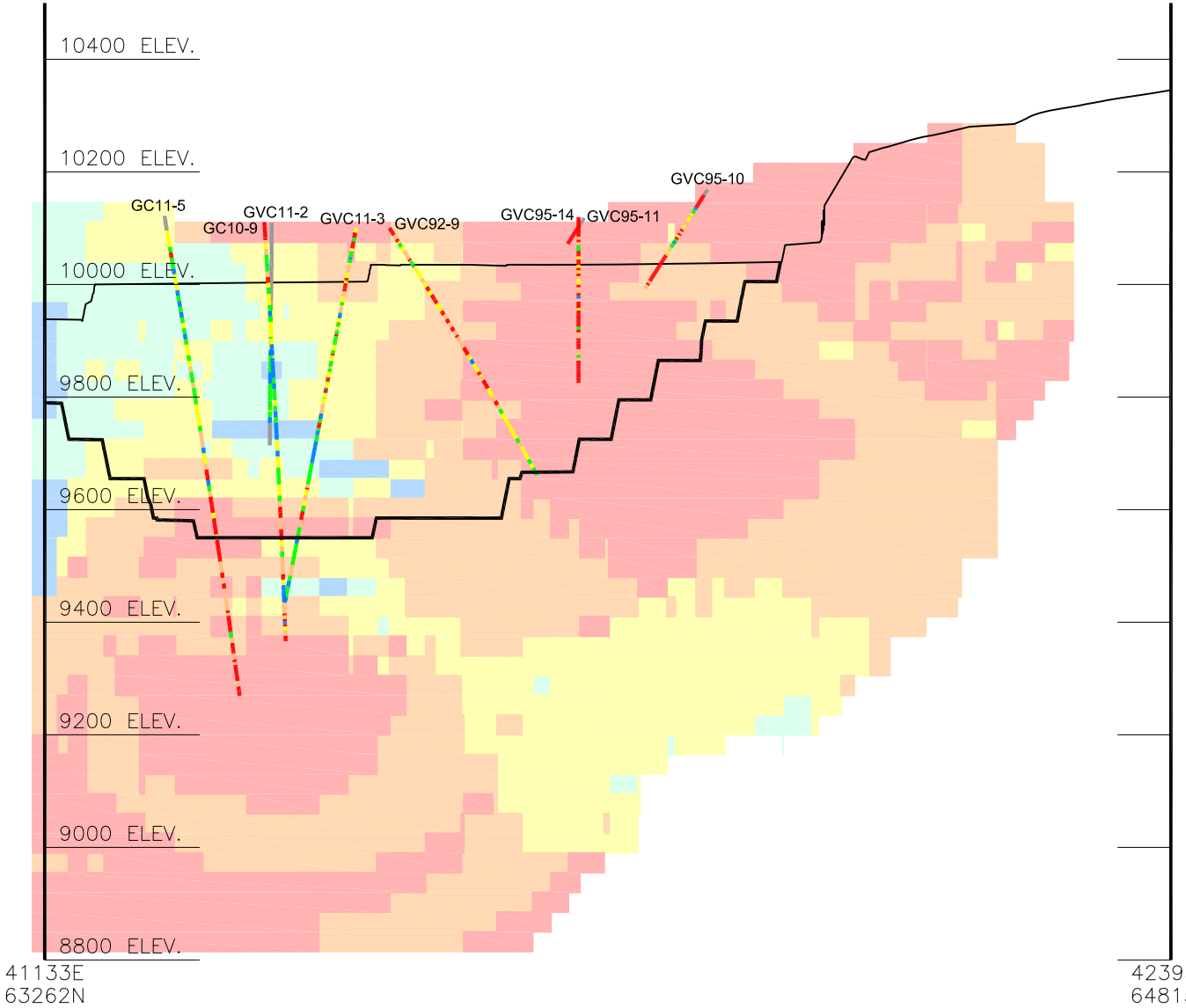
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SECTION WH-2 GLOBAL ANALYSIS AND GEOLOGY (Looking NW)

CRIPPLE CREEK & VICTOR

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\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-28 – WH-2.DWG



SCALE 0 150 300 FEET
(1"=300')

LEGEND

- BLOCK RQD 0-20
- BLOCK RQD 20-40
- BLOCK RQD 40-60
- BLOCK RQD 60-80
- BLOCK RQD 80-100
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN
- HOLE RQD 0-20
- HOLE RQD 20-40
- HOLE RQD 40-60
- HOLE RQD 60-80
- HOLE RQD 80-100
- HOLE NO DATA

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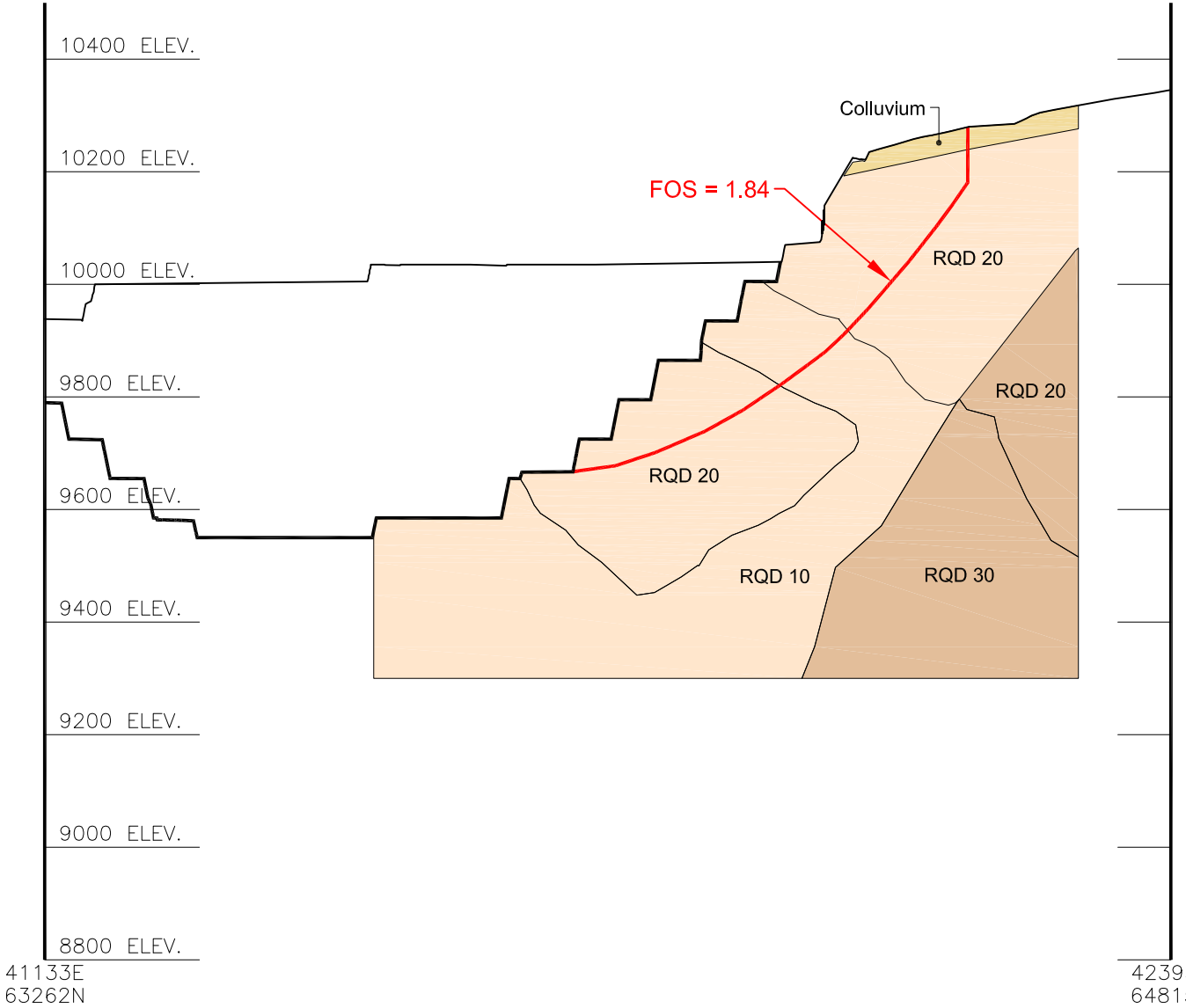
\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-29 - WH-3_RQD_WH-3.DWG

CROSS SECTION WH-3 WITH RQD DATA (Looking NW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300'

FIGURE 6-29



SCALE 0 150 300 FEET
(1"=300')

LEGEND

- GTRCK 1 CRIPPLE CREEK BRECCIA
- GTRCK 4 PRECAMBRIAN
- GTRCK 6 COLLUVIUM / WEATHERED
- MARCH 2011 TOPOGRAPHY
- 03-17-2015 NAU DESIGN

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\2015\NAU_STUDY\REPORT\CHAP_6_GLOBAL SLOPE ANALYSIS\FIGURES\FIG 6-30 – WH-3.DWG

SECTION WH-3 GLOBAL ANALYSIS AND GEOLOGY (Looking NW)

CRIPPLE CREEK & VICTOR

SCALE 1"=300'

FIGURE 6-30

REFERENCES

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APPENDIX A

MONITORING AND SLOPE MANAGEMENT

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INTRODUCTION

With an economically optimized slope design, some degree of slope instability can be expected. Minimization of the adverse effects of slope instability must be accomplished through monitoring, judicious mine planning, and establishment of operational contingencies.

The objectives of a pit slope monitoring program are:

1. To maintain safe operational procedures for the protection of personnel and equipment
2. To provide advance notice of instability so that mine plans can be modified to minimize the impact of slope displacement
3. To provide geotechnical information for analyzing slope displacement mechanisms, for designing appropriate remedial measures, and for conducting future redesign of the slope

A slope displacement does not occur without warning. Prior to major movement, there is measurable deformation and other observable phenomena, such as the development of tension cracks, rock noise, and changes in groundwater-related pore pressure. These phenomena occur from hours to years before major displacement. A slope monitoring program consists of the systematic detection, measurement, interpretation, and reporting of these evidences of slope instability.

A list of commercially available monitoring systems is presented in Table 1. It is a partial list and is only intended to provide some indication of available products. Table 1 is not meant to be an endorsement for any specific company or product. A comparison of monitoring systems is shown in Table 2. In general, expect to pay more for more data. That is, the closer the system is to providing real-time information, the more expensive the system will cost. Low-cost products provide daily readings, at best, and are not automated.

IDENTIFICATION OF POTENTIAL AREAS OF INSTABILITY

The first step in monitoring is the identification of potential unstable areas where the attitude of faults, bedding, and joints is unfavorable or where weak rock and high pore pressure occur. Data for this identification is taken from geologic pit mapping and the past history of instability. This identification is required to maximize the usefulness of surface displacement monitoring, as it is not practical to indiscriminately blanket the pit with survey monitoring. Also, if monitoring is not installed until obvious instability is present, the early part of the displacement history is lost.

SURFACE DISPLACEMENT

Surface displacement measurement by means of tension crack mapping, extensometers, and survey points is still the most cost-effective monitoring method. All three procedures should be used, as no one method would give a completely accurate picture. Figure 1 shows a typical surface monitoring layout.

Tension Crack Mapping

Tension cracks are an early, obvious indication of instability. By systematically mapping the cracks, the geometry of an instability can be better defined. All cracks should be mapped regardless of apparent cause. Often cracks that appear to be the result of local bench displacement or blast damage form a pattern showing an impending larger displacement when plotted on a pit map.

The ends of the cracks should be flagged or marked so that on subsequent visits new cracks or extensions of existing cracks can be identified.

Extensometers

Portable wire extensometers can be used to provide monitoring in areas of active instability and to provide backup for the survey system. These monitoring devices can be quickly positioned and easily moved. A simple extensometer, which can be fabricated in the mine shop, is shown on Figure 2.

The extensometer should be positioned on stable ground behind the last visible tension crack, and the wire should extend out to the unstable area. As warning devices, or for obtaining information on deformation within the displacing mass, wire extensometers can also be placed at any strategic location. Anyone working in the area can make an immediate check on slope movement by inspecting the instruments.

A wire extensometer can be set up as a warning device by affixing a switch several centimeters above the displacement weight; significant displacement will trip the switch. Lights or sirens powered with a 6-volt dry cell battery wired to the switch will warn of slope activity. CNI recommends using a Stevens's continuous drum-type recorder in critical locations (Figure 3).

The length of the extensometer wire should be limited to approximately 200 feet; beyond this length wire sag can produce inaccurate readings. Somewhere between 35 and 50 pounds of counterweight are required for such a length, depending on the tensile strength of the wire. Aircraft control cable, or similar wire that is manufactured to have very little tensile stretch, is recommended for this type of monitoring device. The flexibility and durability of steel cable, compared to the rigidity and brittleness of INVAR wire, outweigh the superior thermal properties of INVAR wire. Temperature fluctuations can be measured and taken into account.

Automatic wire extensometers are commercially available. These instruments are positioned in critical areas of the mine and transmit data via radio signals to a central office. The data can then be easily analyzed through graphical displays. Some systems offer the ability to transmit alerts through the computer network and electronic mail.

Survey Monitoring

Monitoring prism targets with a total station instrument provide a detailed movement history in terms of displacement directions and rates in unstable areas. The preferred layout consists of instrument stations, backsight stations, reference stations on stable ground, and an array of prism targets on the unstable area.

The establishment of stable, sheltered instrument stations from which to conduct the survey is essential. Use of tripods should be avoided. A flat plate with a threaded stud to accept the tribrach on the theodolite should be fabricated and fixed atop a level concrete or metal post. Shelters should be constructed around the instrument stations to protect the instruments and operators from the adverse effects of sun and wind.

Backsights can be taken on other instrument stations or on reference points outside the pit. In addition to a backsight, each instrument station should have a reference point on stable ground. This reference point is used to check the stability of the instrument station and to calibrate the EDM. Rather than making the atmospheric corrections each time the instrument is set up, a prism should be fixed on the reference point and the EDM adjusted to get the same distance as the previous setup. Since the displacement measurements are relative, reproducibility is more important than absolute distances and elevations.

Robotic total stations are becoming more commonplace to collect displacement data automatically. These instruments operate on the same principle as a surveyor-operated

instrument. The real benefit from the robotic station is that measurements have better precision and are generally more accurate than manual surveying, and the robot can operate 24 hours per day. The limitations are generally the same between robotic and manual total stations.

Due to the increased data collection, software is needed to automatically scan the data and then issue alerts when pre-defined thresholds are exceeded.

The suggested minimum target layout on an unstable area is to place six prisms in a vertical section down the center of the unstable area and a horizontal row of five prisms across the center of the area, depending on the size of the instability and budget constraints. The end prism of the vertical and horizontal sections should be outside the suspected unstable area to check on expansion of the unstable area. Assuming the sections can share a target, a total of nine prisms would be required.

The most accurate way to survey monitoring prism points is to have the instrument set up in line with the predominant displacement vector. This technique takes advantage of the fact that the EDM distance measurement is more accurate than the angle measurement. In some cases, however, this is not feasible because there is too large a distance (over 1000 meters) between the instrument and the prism.

Global Positioning Systems

Manufacturers of satellite-based global positioning systems (GPS) are offering stand-alone instruments that monitor a specific point on a slope. These units are usually solar-powered and contain a GPS receiver and a radio to transmit coordinate data to a central office. These systems offer highly accurate displacement data. A disadvantage of these units is that they could be at risk of being damaged in a slope failure due to their necessary placement on a slope.

Slope Radar

Radar technology is being used to monitor sub-millimeter slope movement of entire pit slopes. Portable radar units can be maneuvered to a viewpoint and then scan above active mining areas. The slope is monitored in near real-time. Advantages of slope radars include accuracy, and it is unaffected by rain, fog, or dust. The system allows for increased operator confidence in high-risk areas.

InSAR

A relatively new technology is Interferometric Synthetic Aperture Radar (InSAR) that uses a radar instrument mounted on an earth orbiting satellite. At least two radar snapshots are required. The differences between the snapshots are measured using software and ground deflection over wide areas can be determined. The system is not real-time monitoring.

Other Surface Displacement Devices

When tension crack displacement is predominantly vertical, a tiltmeter, consisting of a bar placed across the crack with a protractor and pendulum, can be used to measure displacement. A mercury switch on this bar can be attached to a warning light. Manometers can also be used to monitor vertical displacement across tension cracks.

Simple wooden surveying lath can be installed across tension cracks. One lath can be placed flat on the ground on the upper block, crossing the crack. A second lath driven vertically into the lower block and against to the first lath, can be used to mark both horizontal and vertical displacement.

A simple pin-set is two nails or spikes driven into the ground on either side of a tension crack. The distance between the two pins can be measured and recorded.

SUBSURFACE DISPLACEMENT

Surface displacement measurements do not determine the subsurface extent of instability, although it is possible to make inferences from displacement vectors. There are situations, though, where subsurface data are necessary.

Shear Strips

Shear strips in a borehole will help to locate the position where the hole is cut off. Either commercial segmented strips or a coaxial cable with a fault finder can be used; however, these systems have the limitation of being go/no-go devices. TDR systems are now generally preferred over shear strips because of their ability to detect deflection in the cable.

Time Domain Reflectometry (TDR)

Time Domain Reflectometry (TDR) has also been utilized to monitor slope movement in a variety of geotechnical settings. In stability monitoring applications using

TDR, a coaxial cable is installed in a vertical borehole passing through the region of concern. The electrical impedance at any point along the coaxial cable changes with deformation of the insulator between the conductors. A brittle grout surrounds the cable to translate earth movement into an abrupt cable deformation that shows up as a detectable peak in the reflectance trace. In another application, TDR can be used in horizontal trenches on a pit crest to provide indications of tension cracking.

Borehole Inclinometers

A borehole inclinometer that measures the angular deflection of the hole will give the deformation normal to the hole. Specialized inclinometer casing contains grooves that align the instrument, or accelerometer, within the casing as it travels through the hole. The initial reading provides a baseline against which all subsequent readings are compared. Any shear planes become apparent over several weeks or months and can be used to identify culprit structures or failure volume.

Borehole Extensometers

Borehole extensometers will give the deformation parallel to the borehole. However, because they are costly and difficult to use; borehole extensometers are usually special application devices.

Piezometers

The correlation between pore pressure and slope stability is well established, both in theory and in practice. Measuring groundwater levels is an important part of monitoring, and simple standpipe piezometers are usually sufficient. In cases where the permeability is low (due to fine-grained clays, for instance) electrical or pneumatic piezometers should be considered to measure actual pore pressures.

PRECISION, RELIABILITY, AND COST

The number of different devices that can be used for monitoring, as well as the precision and sophistication of the devices, are functions of the ingenuity, the time, and the budget of the engineer in charge of monitoring. Since none of these factors are infinite, hard choices must be made. Some general guidelines for prioritizing and decision-making follow:

- **Measure the obvious things first**.
  Surface displacement is the most direct and most critical aspect of slope instability.

- **Simpler is better.**
  The reliability of a series system is a product of the reliability of the individual components. A complex electronic or mechanical device with a telemetered output to a computer has significantly less chance of being in operation when needed than two stakes and a tape measure.

- **Precision costs money**.
  The cost of a measuring device is often a power function of the level of precision. Measuring to ∀1 centimeter is inexpensive compared to measuring to ∀.0001 centimeter. A micrometer is unnecessary for monitoring slope movement that has a velocity of five centimeters per day.

- **Redundancy is required**.
  No single device or technique tells the complete story. A single extensometer or survey point cannot indicate the area involved in the instability, and if it is damaged or destroyed, the continuity of the record is lost.

- **Timely reporting is essential**.
  The data collection and analysis must be rapid enough to provide information in time to make decisions.

MONITORING SCHEDULE

A definite monitoring schedule should be established. If shooting in the monitoring points is left to the mine surveyor to do when he "gets time," the results will be erratic at best.

The frequency of monitoring is a function of the precision of the system, the rate of movement, and how critical the area is. Table 3 provides a suggested schedule. In the event of heavy rain or a large blast in the area, additional measurements should be taken.

Cooperation between operations and engineering is important. Equipment operators often have an intuitive feel for ground conditions. Any changes in the condition of an area observed by operators should be reported to engineering for follow-up.

DATA REDUCTION AND REPORTING

The following measurement or calculations should be made for each survey reading:

1. Date of reading, time, incremental days between readings, and total number of days the survey point has been established

2. Coordinates and elevation
3. Magnitude and direction of horizontal displacement
4. Magnitude and plunge of vertical displacement
5. Magnitude, bearing, and plunge of resultant displacement vector
6. Rates (velocities) of horizontal, vertical, and resultant (total) displacements

Both incremental and cumulative displacement values should be determined. Calculating the cumulative displacement from initial values rather than from summing incremental displacements minimizes the effect of occasional survey aberrations. Table 4 is an example of reduced monitoring data.

Slope displacements are best understood and analyzed when the monitoring data are graphically displayed. For engineering purposes, the most useful plots are:

1. Horizontal position
2. Vertical position (elevation versus change in horizontal position, plotted on a section oriented in the mean direction of horizontal displacement)
3. Displacement vectors
4. Cumulative total displacement versus time
5. Incremental total displacement rate (velocity, usually in meters per day) versus time

All graphics should be kept up-to-date and should be easily reproducible (for ease of distribution). By studying several graphics simultaneously, the movement history of a particular slope can be determined.

The velocity-versus-time plot is usually constructed on semi-log paper rather than on a linear scale. This allows a greater range of displacements to be plotted without losing the precision required for small measurements. Also, this type of graph is compatible with current monitoring techniques and analyses of slope movement kinematics.

Precipitation data should also be recorded to evaluate possible correlations with slope displacement. A gauge (or gauges) located at the mine site can be used to measure occurrences

and amounts of precipitation. In addition, measurement of the average daily temperatures will provide some indication of freeze and thaw periods.

The location of mining areas, the number of tons mined, and blasting patterns in the area should also be recorded on a regular basis, because slope displacements are often associated with mining activity. One method of cataloging this information is to plot the mining area and then note the number of tons mined and the data on a plan map of the pit. A histogram can be made of tons mined versus time, and this plot can then be compared to the total displacement graphs.

Monthly Slope Stability Report

A formal, monthly slope stability report should be prepared. This report should contain the data listed in Table 5 and recommendations on the appropriate response to current instability. This should ensure that mine management receives the appropriate information and provides the discipline to document slope behavior. Direct, informal communication should also be maintained with pit operations on a daily basis when there is mining in an actively displacing area.

Interpreting Displacement Data

Often there are several possible slope displacement modes for a pit slope, and it may not be clear, particularly at the onset of movement, which mode geometry is active. Displacement vectors are useful in determining the displacement geometry. Figure 4 is a hypothetical example showing a possible plane shear along a fault, F1, and a possible wedge of faults, F2 and F3. The difference between the two would be significant since the F1 plane shear would affect the building, while the wedge would not. Plotting the displacement vectors on a Schmidt plot shows that the displacement is in the direction of the wedge, not the plane shear.

Velocity Prediction

Most techniques used to calculate slope stability are static, rigid block, limiting-equilibrium analyses. If the driving forces exceed the resisting forces, the slope is considered unstable.

These analyses cannot be used to predict post-displacement deformation because the dynamic energy relationships of a moving block are not considered in this type of analysis. Therefore, our knowledge of the behavior of unstable slopes is largely empirical.

Predicting slope movement is further complicated by changes in the excess driving force that can occur with displacement. The shear surface is rarely a smooth plane, and shearing of

asperities can reduce the resisting force. Where the shear surface approximates a rotational shear, the driving force decreases as the toe heaves and the top of the slide drops.

The cyclic nature of slope displacement can also be explained by changes in pore pressure and mining activity. For example, in the case of a water-filled tension crack, displacement will cause the crack to widen and the water level to drop, reducing the driving force. As the crack fills again, the driving force will increase.

Given the complexity of slope displacement, no single mathematical relationship is sufficient for predicting slope behavior. On the basis of an examination of slope instability and displacement records, Zavodni and Broadbent have postulated two displacement stages: (1) a regressive stage, during which the slope will restabilize if some external disturbance is removed, and (2) a progressive stage, where the slope displacement will progress to the point of total collapse unless active control measures are taken.

A progressive displacement requires the following conditions, as shown on Figure 5:

1. The displacing mass is free to move.
2. The total driving force does not decrease with displacement.
3. The shear strength drops with displacement (peak shear strength being greater than residual shear strength).

Simple daylighted wedge and plane-shear displacement geometries would be examples of potential progressive displacements.

Where the stress/strain curve shows no peak shear strength and the driving force is close to the residual, the displacement would be steady-state.

A regressive slope displacement would be one in which either the driving force decreases with displacement or the resisting force increases with displacement, or both. This condition occurs where the displacing slope has an active block and a passive block and displacement results in a shift of material from the active to the passive block. A deep-seated rotational shear is an example of a regressive type instability. A slope displacement that toes out at or below the bottom of the pit so that the displacement at the toe must be horizontal or upward would also be a regressive geometry.

Regressive instability within a material exhibiting peak shear strength may display an initial progressive displacement resulting from the drop in shear strength with displacement.

Regressive slope displacements can become progressive because of changes in geometry resulting from mining or displacement and because of pore pressure changes. For example:

1. A non-daylighted geometry can be daylighted by mining at the toe.
2. Breakup of the rock mass at the toe of a non-daylighted wedge or plane shear can result in a new shear surface.
3. Increase in pore pressure along the shear surface of a passive block can reduce the effective shear strength to the point at which the block becomes active.

Although the displacement history of an unstable slope may be complex, projections of velocity are useful estimators of future displacement rates, particularly if new projections are made as new data points are obtained.

These projections can be made by fitting linear segments to the semi-log plot of velocity versus time, as shown on Figure 6. The mathematical relationship for these projections would be:

$$V = V_o e^{Bt}$$

Where:

V = velocity,
V_o = initial velocity,
B = a constant (i.e., the semi-log slope), and
t = time since V_o.

This is the relationship used by Zavodni for predicting collapse. There may not be an abrupt collapse but a continued acceleration. The more general relationship is probably of the form:

$$V = V_o e^{Bt^C}$$

Where the linear fit is a special case, with C equal to 1.

The displacement record of instabilities does not indicate that there is a universally applicable critical velocity or total displacement criteria for predicting large rapid movements. Regressive slope displacements in soft materials have had displacement rates of up to two meters per day without collapse; whereas a thin, steeply dipping slab might collapse with only a few centimeters of displacement.

For large slope displacements (+100,000 tonnes), the following guidelines are recommended:

1. For a progressive geometry and a progressive velocity curve (increasing velocity), the area should be cleared when the velocity exceeds about 10 centimeters per day.

2. For a regressive displacement geometry, the area should be cleared when the velocity exceeds 15 centimeters per day. When the displacement rate stabilizes below 15 centimeters per day, mining can be continued. With a predictable displacement history, mining can be continued up to about 30 centimeters per day.

3. Projections of the velocity curve should be made so that advance notice can be given to operations, predicting the time when an area may have to be cleared.

SLIDE MANAGEMENT

When mine slope instability occurs several responses are possible.

1. Leave the unstable area alone
2. Continue mining without changing the mine plan
3. Unload the displaced area through additional stripping
4. Leave a step-out
5. Do a partial cleanup
6. Mine out the instability
7. Support the unstable ground with cable bolts
8. Dewater the unstable area

The choice of option or combination of options depends on the nature of the instability and its operational impact. Each case should be evaluated individually, cost-benefit comparisons should be conducted, and the following guidelines should be observed.

1. When instability is in an abandoned or inactive area, it can be left alone.

2. If the displacement rate is low and predictable and if the area must be mined, monitoring the displacement while continuing to mine may be the best action.

3. Even though unloading has been a common response, in general it has been unsuccessful. In fact, in some situations involving high water pressure, unloading actually decreases stability.

4. Step-outs have been used successfully in several mines. The choice between step-outs and cleanup is determined by weighing the trade-off between the value of lost ore and the cost of cleanup.

5. Partial cleanup may be the best choice where an instability blocks a haul road or displaces onto a working area. Only the material that is impeding operations should be removed.

6. Where the instability occurs on a specific structure and there is competent rock behind the structure, mining out the slope displacement may be the optimum choice.

7. Mechanical support may be the most cost-effective option when a crusher, conveyor, or haul road must be protected.

8. Where high water pressure exists, dewatering is an effective method of stabilization that may be used in conjunction with other options.

CONTINGENCY PLANNING

To avoid an "after-the-fact" crisis response to forced deviation from a rigid mine plan, mine planning should have the flexibility to respond to slope instability. Contingency plans should be prepared in advance so that the response to slope instability is well thought out. Operational flexibility should be built into the mine plan. Adequate ore should be exposed and accessible so that production is available from several different locations; there should be more than one access road into the pit for service vehicles, and production scheduling and budgeting should have a provision for slide cleanup.

Table 1

Commercially Available Monitoring Systems

Instrument	Manufacturer	Website
Robotic Total Station for Prism Monitoring	Leica Geosystems AG	www.leica-geosystems.com
Robotic Total Station for Prism Monitoring	Geodimeter® / Trimble Navigation Ltd.	www.trimble.com
Automatic Slope Extensometer	Call & Nicholas Instruments, Inc.	www.slideminder.com
Automatic Slope Extensometer	Modular Mining Systems, Inc.	www.mmsi.com
GPS	Leica Geosystems AG	www.leica-geosystems.com
GPS	Pinnacle Technologies, Inc.	www.3dtracker.com
GPS	Orion Monitoring Systems, Inc.	www.orionmonitoring.com
Slope Stability Radar	Groundprobe Pty Ltd	www.groundprobe.com
Slope Stability Radar	Reutech Radar Systems (Pty) Ltd.	www.rrs.co.za
Interferometric Synthetic Aperture Radar (InSAR)	AMEC Plc.	www.amec.com
TDR	RST Instruments Ltd.	www.rstinstruments.com
TDR	Call & Nicholas, Inc.	www.cnitucson.com
Inclinometer	RST Instruments Ltd.	www.rstinstruments.com
Inclinometer	Slope Indicator Co.	www.slopeindicator.com
Borehole Extensometer	RST Instruments Ltd.	www.rstinstruments.com
Borehole Extensometer	Slope Indicator Co.	www.slopeindicator.com
Piezometer	RST Instruments Ltd.	www.rstinstruments.com
Piezometer	Slope Indicator Co.	www.slopeindicator.com

NOTES:

These are examples of commercially available systems or services. There are often several manufacturers of similar products that are not listed here. The appearance of a particular product or company in this table does not represent an endorsement.

Table 2

Comparison of Monitoring Systems

Instrument	Monitoring Location	Coverage	Frequency of Reading	Cost
Lath / Pin Set	Surface	Point	Daily	Low
Manual Prism	Surface	Point	Daily	Low
Robotic Prism	Surface	Point	Hourly	High
Manual Slope Extensometer	Surface	Point	Daily	Low
Automatic Slope Extensometer	Surface	Point	Real-time	Moderate
GPS	Surface	Point	Real-time	High
Slope Stability Radar	Surface	Area	Real-time	High
Interferometric Synthetic Aperture Radar (InSAR)	Surface	Area	Weekly - Monthly	High
Shear Strip	Sub-surface	Linear	Daily - Monthly	Moderate
TDR	Sub-surface	Linear	Daily - Monthly	Moderate
Inclinometer	Sub-surface	Linear	Weekly - Monthly	Moderate
Borehole Extensometer	Sub-surface	Point	Weekly - Monthly	Moderate
Piezometer	Sub-surface	Point	Daily - Monthly	Low - Moderate

Table 3

Suggested Monitoring Schedule (1)

Mining	Slope Velocity (ft/day)	Frequency of Visual Inspection (2,3)	Frequency of Reading Extensometers	Frequency of Crack Mapping (4)	Frequency of Surveying Prisms	Frequency of Reading Piezometers
Active	<0.01	Daily	Weekly	Monthly	Monthly	Monthly
	0.01-0.05	Daily	Daily	Weekly	2 x Month	Monthly
	0.05-0.20	Each Shift	Daily w/ Continuous Recorder	Weekly	Weekly	Weekly
	>0.20	2 x Shift	2 x Day Recorder	Daily	Daily	2 x Week
Inactive	<0.01	Weekly	Monthly	Monthly	Monthly	Monthly
	0.01-0.05	Weekly	Weekly	Monthly	Monthly	Monthly
	0.05-0.20	Daily	2 x Week w/ Recorder	Weekly	2 x Month	Monthly
	0.2-0.50	Daily	Daily w/ Continuous Recorder	2 x Week	Weekly	Weekly
	>0.50	2 x Day	Daily w/ Continuous Recorder	Daily	Daily	2 x Week

NOTES:

1. Situations involving facilities, such as a crusher or conveyor, or where small displacements would result in damage to the facility require more precise monitoring methods and more frequent measurements.
2. MSHA requires inspection of the working face at the beginning of each shift and weekly inspections of the high wall. Visual inspection can be done by operations personnel.
3. Visual inspection can include reading extensometers. The fastest moving extensometer should have a warning light and siren.
4. Additional crack mapping and survey monitoring should be done if:

   (a) Changed conditions are observed during visual inspection; or

   (b) There is significant rainfall or seismic activity.

Table 4

Example Monitoring Output Station: SP1 8/7/86

	Hour	Day	Month	Year	Lat.	Dep.	Elev.
1	9:00	18	7	86	.130	- .240	- .420
2	9:00	21	7	86	1.370	- .920	- .400
3	9:00	22	7	86	1.890	-1.070	-1.010
4	9:00	23	7	86	2.090	-1.440	-1.210
5	9:00	24	7	86	2.460	-1.760	-1.500
6	9:00	25	7	86	2.860	-2.100	-1.780
7	9:00	28	7	86	3.940	-2.920	-2.480
8	9:00	29	7	86	5.010	-3.700	-2.860
9	9:00	30	7	86	5.480	-3.910	-3.180
10	9:00	31	7	86	5.780	-4.230	-3.430
11	9:00	1	8	86	6.230	-4.490	-3.660
12	9:00	4	8	86	7.440	-5.480	-4.600

		HORIZONTAL			VERTICAL			TOTAL	
Date	Days	Dist. ft	Bear.	Vel. ft/day	Dist. ft	Angle	Vel. ft/day	Dist. ft	Vel. ft/day
INCREMENTAL DATA									
7/18/86	199	0							
7/21/86	202	3	1.41	331	0.471	.02	1	.007	1.41	0.471
7/22/86	203	4	0.54	344	0.541	-.61	-48	.610	0.82	0.815
7/23/86	204	5	0.42	298	0.421	-.20	-25	.200	0.47	0.466
7/24/86	205	6	0.49	319	0.489	-.29	-31	.290	0.57	0.569
7/25/86	206	7	0.52	320	0.525	-.28	-28	.280	0.59	0.595
7/28/86	209	10	1.36	323	0.452	-.70	-27	.233	1.53	0.509
7/29/86	210	11	1.32	324	1.324	-.38	-16	.380	1.38	1.378
7/30/86	211	12	0.51	336	0.515	-.32	-32	.320	0.61	0.606
7/31/86	212	13	0.44	313	0.439	-.25	-30	.250	0.50	0.505
8/01/86	213	14	0.52	330	0.520	-.23	-24	.230	0.57	0.568
8/04/86	216	17	1.56	321	0.521	-.94	-31	.313	1.82	0.608
CUMULATIVE DATA									
7/18/86	199	0							
7/21/86	202	3	1.41	331	0.471	0.02	1	.007	1.41	0.471
7/22/86	203	4	1.95	335	0.486	-0.59	-17	.148	2.03	0.508
7/23/86	204	5	2.30	329	0.460	-0.79	-19	.158	2.43	0.486
7/24/86	205	6	2.78	327	0.464	-1.08	-21	.180	2.98	0.497
7/25/86	206	7	3.30	326	0.472	-1.36	-22	.194	3.57	0.510
7/28/86	209	10	4.66	325	0.466	-2.06	-24	.206	5.09	0.509
7/29/86	210	11	5.98	325	0.544	-2.44	-22	.222	6.46	0.587
7/30/86	211	12	6.49	326	0.541	-2.76	-23	.230	7.05	0.588
7/31/86	212	13	6.92	325	0.532	-3.01	-24	.232	7.54	0.580
8/01/86	213	14	7.43	325	0.531	-3.24	-24	.231	8.11	0.579
8/04/86	216	17	8.99	324	0.529	-4.18	-25	.246	9.92	0.583

Table 5

Monitoring Data Presentation

GRAPHS	MAPS AND SECTIONS
• Cumulative Displacement vs. Time	• Pit Map with Location of Unstable Areas
• Velocity vs. Time (feet/day, semi-log plot)	• Locations of Monitoring Points with Displacement Vectors
• Precipitation vs. Time	• Tension Crack Map
• Water Levels vs. Time	• Horizontal Plot of Location with Time
• Mining vs. Time	• Vertical Plot of Location with Time
	• Map of Piezometric Surface
	• Cross Section of Unstable Area

APPENDIX B

CONTROLLED BLASTING

CONTROLLED BLASTING

&

BLAST MONITORING PROCEDURES

CALL & NICHOLAS, INC.

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1.0 INTRODUCTION

The following text is an overview of blasting and blast monitoring procedures that CNI recommends to all clients. Blasting issues addressed in this chapter do not necessarily indicate that similar problems exist at your property, but are merely recommendations for blast optimization.

Production blasting can have significant impact on slope design. Excessive blast-induced damage can extend into the final pit wall and can result in increased back break and flatter bench face angles. To obtain steeper slope angles, it is necessary to develop and maintain a comprehensive blasting program that will result in minimized over break.

Blasting produces a vibrational ground motion that can be measured in terms of peak particle velocity. Empirical observations of the relationship between peak particle velocity and blast damage at a copper mine in Arizona are provided as an example in Table 1.

Within a production blast, a vibration of +25 inches per second is generally necessary for fragmentation of the rock. However, if damage extends into the final wall, backbreak will be increased, resulting in narrower catch benches. This may require flattening the interramp slope angle to achieve the required catch-bench width.

2.0 CONTROL OF THE PRODUCTION BLAST

Assuming that the damage caused by a blast increases in proportion to the weight of the explosive used, any reduction in explosive consumption will lead to a reduction in damage. Optimization of the production blast is perhaps the most important step in controlling slope damage. If better fragmentation or digging conditions can be achieved by using less and more evenly distributed explosive, there will be less energy available to cause damage.

Good movement of the blast to free face(s) results in better digging and less damage to the slopes. Because blasting energy follows the path of least resistance, a blast that is choked against a final wall will cause more damage than a blast that is free to move away from the slope. The following steps should be taken to optimize the production blast.

1. Blasthole patterns should be carefully planned, staked, and drilled. Establishing patterns by the pacing method should be discontinued in favor of more accurate tape or survey methods.
2. Choke blasting into excessive burden or broken muck should be avoided.
3. The front row charges should be adequate to move the front row burden.

4. The main charge and patterns should be optimized.
5. Adequate delays should be used to ensure movement to the free face(s).
6. The back row holes should be offset from the final wall dig line by the distance at which damage could be expected based on seismic velocity data. Trial and error should be used to adjust the back row charges further to control backbreak.
7. Delays should be used to minimize the maximum instantaneous charge (MIC) so that the vibration levels (i.e., seismic velocities) are less than 25 inches/second at the final wall.
8. One hole initiated per delay is recommended to limit overbreak at the final wall.

3.0 PREDICTIONS OF PEAK PARTICLE VELOCITY

The widely accepted relationship for peak particle velocity is

$$V = K\,(D/W^{1/2})^{m},$$

where:

V = peak particle velocity (inches/second),
K = constant based on site-specific conditions,
D = distance from the blast (feet),
W = weight of explosive detonated per delay (lbs), and
m = constant based on site-specific conditions.

The values of the constants, K and m, are dependent on the elastic properties and fracture intensity of the rock. These constants can vary both between and within rock types. For typical downhole blasting, K ranges from 26 to 260, and m is commonly around -1.6. Figure 1 shows typical ranges of velocity versus scaled distance for downhole blasting (Oriard, 1971).

In the absence of site-specific seismic velocity constants, Oriard's data on the typical ranges of velocity versus scaled distance can be used to estimate likely average seismic velocity constants. This information can be used to predict vibration damage potential until seismic constants can be determined. Figure 2 is a plot of peak particle velocities (V) based on average Oriard data versus scaled distance ($D/W^{1/2}$). Values of 143.0 for K and -1.60 for m (slope of the line) are indicated on Figure 2.

4.0 CONTROLLED BLASTING ZONE

The distance at which damage can be expected for any weight of charge can be calculated from Figure 2. This figure shows the damage zone distance in feet (based on 25 inches/second)

for various charge weights based on one hole per delay. For example, if the pounds of powder per delay is 1000, the last row of production holes should be about 90 feet (27 meters) away from the final wall, assuming a 25 inches/second damage criteria and one hole per delay.

Figure 2 is useful for determining the distance that the last row of production blastholes in a blasthole pattern should be offset from the final wall. The 25-inches-per-second damage criterion should be used for all rock types except for very hard and dense rocks, for which up to 100 inches/second may be needed for adequate fragmentation. If a shovel cannot dig this distance behind the shot, some type of controlled blasting (e.g., buffer blasting, cushion blasting, pre-splitting, etc.) may be needed.

In view of the importance of blast design adjacent to the pit walls, design of the blasthole pattern from the back to the front of the shot is justified, provided that front row charges are also carefully designed to ensure adequate movement of the front row burden. Locally, problems of excessive front row burden should be overcome by the drilling of fill-in or "easer" holes, or by slightly increasing the charge weight in front row holes when extra holes are not justified.

5.0 BLASTING PROCEDURES

A discussion of the blasting procedures, which affect slope stability, is presented below.

5.1 Documentation

Considering the costs associated with drilling and blasting and the impact that drilling and blasting have on materials, handling, comminution, and slope stability, it is critical that complete records be maintained for all blasting activities. A blast report should be designed to include the following pre- and post-blast data. This information is extremely important for benches near the planned final wall.

1. The rock type(s) contained in the blast pattern
2. A surveyed map of blasthole pattern as drilled, showing numbered hole locations, delay sequence, and location of free face
3. Tabulated data for each hole, including hole depth, water level, ANFO equivalent charge, charge rise, and stemming depth
4. A photograph of the free face before blasting
5. A surveyed map of backbreak tension cracks generated by the blast

6. Comments characterizing the blasting results, such as possible cutoffs, degree of fragmentation, direction of throw, etc.
7. A photograph of blasted material taken from the same point as the pre-blast photo

A post-mining report should be completed immediately after the removal of all material corresponding to a given blast. It should include:

1. A surveyed map of toe and crest locations
2. Measured average and minimum bench face angles taken about every 15 meters of the entire length of bench corresponding to the blast
3. Comments characterizing material removal such as digability, need for secondary blasting, hard toe, condition of resulting bench face, etc.

If these parameters are consistently recorded for every blast, it is then possible to evaluate the effects of changes on ground conditions or blasting procedures. Since blasting procedures may have to be modified for different areas or rock types, it is essential that rock type be recorded along with the blast information. Parameters relating to the blast geometry (hole spacing, burden, depth, etc.), charge per hole, and delay sequence are essential for evaluating powder factors, fragmentation, and overbreak. The follow-up procedures for mapping backbreak tension cracks, measuring bench face angles, monitoring secondary blasting and digability, and reviewing photographs are a means of standardizing the evaluation process.

Once a standardized method of documentation has been developed, it will be possible to optimize blasting procedures by modifying various parameters and evaluating the results. Changes in procedure should be made by varying one parameter at a time, starting with the more basic parameters such as pattern, charge, hole diameter, and delay sequence. More complex procedures, such as decked charges and perimeter blasting or pre-splitting, should be deferred until the basic parameters of production blasting have been optimized.

5.2 **Ground Conditions**

The first step that should be undertaken in a blast design program is the development of working-scale plan maps which provide geological and geotechnical information to assist in the prediction of ground conditions. The most important geological information included on such a map would be rock type and fracture frequency. Additional data would be alteration, hardness,

drillability (from daily rotary drill reports), *in situ* seismic velocity, unconfined compressive strength, and shear strength.

The next step includes relating blasting practices and evaluation (from blast records) with ground conditions; eventually it will become apparent which geological or geotechnical indices or parameters most significantly affect blast design.

Another objective would be to determine which blast design(s) produce the most desirable results for the various ground conditions. A set of plan maps showing daily shovel advances could be used to evaluate blast effectiveness in terms of fragmentation, digability and backbreak. Once the critical geotechnical parameters are determined, they can be incorporated into a computer-based geotechnical model.

Of course, the effectiveness of such a program is dependent on the quality of data collected. Therefore, it is important that blast designs and results be adequately documented and evaluated.

5.3 **Real Costs of Blasting**

The motivation for geotechnical input in blast design is the potential for improved fragmentation, elimination of excessive rock slope disturbances, and the resultant improvement in economics. An appreciation of the significant influence of fragmentation on the overall operation should encourage the utilization of rock mechanics data in blast design. The emphasis of the blasting program should be on obtaining the optimum degree of fragmentation to lower the combined cost of drilling, blasting, loading, haulage, and crushing, rather than reducing the cost of drilling and blasting alone.

6.0 BLASTING PARAMETER DISCUSSION AND RECOMMENDATIONS

6.1 **Blasthole Diameters**

Although the effect of large-diameter (12□inch) holes is to decrease drilling costs, the effect upon overall mine economics is more difficult to evaluate. Large-diameter holes and expanded patterns may reduce drilling and blasting costs, but if this results in inadequate explosive column height, poor fragmentation due to uneven charge distribution and decreased slope stability, then overall mining costs may increase. It may be preferable to use densely

spaced, smaller-diameter holes, especially near final pit walls, to reduce instantaneous charge weights, improve fragmentation, and minimize overbreak.

When blasted, hard blocky rock separates into blocks defined by pre-existing fractures. Intact, unmanageable blocks, are frequently found displaced in the muck pile. To ensure that no blocks remain intact following the blast, it is necessary to place explosives within each individual block. Large-diameter blastholes and expanded patterns increase chances of isolating large unmanageable, pre-existing blocks. Drilling smaller holes, and using a smaller pattern, increases the probability that individual blocks will contain explosives.

6.2 **Blasthole Patterns**

The accuracy of the drilling determines the efficiency of a blast and, to a large extent, the amount of unnecessary blast damage. Optimal blast results cannot be produced with a large random scatter in borehole positioning and hole direction.

The last row of holes is particularly critical to the amount of variation in the blast results. A two-percent variation in hole location may require as much as an eight-percent variation in charge to maintain a constant powder factor. Scatter in borehole position results in substantial powder factor variation within individual blasts.

Imprecise blasthole layout makes it impossible to achieve consistent blasting results. Inconsistency results in a tendency to use high overall powder factors to be on the "safe side." Obviously, in addition to being wasteful, more explosive will produce more pit wall damage. Vibration and damage caused by a given charge depend on the ease with which the charge breaks loose its burden. Thus, hole deviations and positioning errors that increase the burden or the degree of fixation (constriction) always make the charge produce more damage to the remaining rock than it would otherwise have done (Langefors & Kihlstrom, 1963). This is true for all holes in the blast, not just the contour holes. Thus, blasthole patterns should be carefully planned, staked, and drilled. Establishing patterns by the pacing method should be discouraged in favor of more accurate tape or survey methods, and the blasthole pattern stakes should be firmly positioned out of the way of local traffic.

Use of square or staggered patterns seems to be a matter of personal preference, and the effectiveness of each is dependent on the delays and firing sequence used. However, square patterns are easier to lay out, and therefore, are usually more precise. A square pattern is shown

on Figure 3. This pattern, when used with the firing sequence shown, results in a burden to spacing ratio of 1:2. Patterns should be limited to a maximum of three rows to ensure proper burden movement toward the free face; this will minimize overbreak caused by excessive confinement of the back row charges.

6.3 Delays and Firing Sequence

Studies at several Kennecott properties have shown that delayed blasting not only improves slope stability, but also results in better fragmentation and displacement, and less cleanup time for multiple-row shots.

All production blasting should be done using one hole per delay with a minimum delay between holes of 17 to 25 milliseconds. Proper firing sequence will ensure movement toward the free face and help avoid choked situations. Maximum instantaneous charge (MIC) levels should be kept as low as possible. By using one hole per delay, it is possible to maintain MIC levels at or below 1200 pounds ANFO equivalent.

Downhole delays should be used in conjunction with surface delays to eliminate cutoffs by ensuring that trunk lines and down lines have fired before adjacent charges have been initiated. Duplication of lines and primers is recommended to ensure initiation of all charges.

A square pattern for production blasting, which shows the recommended layout, delay sequence, and spacing to burden relationships, is shown on Figure 3.

6.4 Stemming

Stemming using drill cuttings is a generally accepted procedure for directing explosive effort into the rock mass. Too little stemming or too high an explosive rise will result in loss of energy to the atmosphere, creating excessive air blast and fly rock. Too much stemming or too little explosive rise will result in poor fragmentation of the upper portion of the bench and poor utilization of drill holes.

Studies have shown that pea gravel is the most effective stemming material. It is small enough not to damage down lines, primers, etc., yet in compression from the detonation, it forms a very effective plug.

Experience has shown that a stemming depth of 0.7 times the effective burden is a good first approximation. The judicious use of pea gravel may result in financial savings, especially in

massive competent rock, such as magnetite rich material, in which coarser stemming would improve charge rise and fragmentation in the upper part of the bench.

6.5 Free-Face Blasting

A clean free face should be developed by excavation and the front row hole layout should be adjusted to develop a manageable front row burden. Adjustments to perimeter blast patterns which are laid out from back to front should be made in the front rather than the back row of holes.

Front row charges should be carefully designed to ensure adequate movement of front row burden. The mean burden method or any similar method can be used. Normal production powder factors should be adequate to ensure front row burden movement. When a shovel is advanced toward a drilled front row, cleanup to a smooth free face at an optimum distance from that front row should be controlled by a blasting dig line. The blasting dig line should be established by the blasting foreman after each blast or surveyed when final limits of the excavation are reached.

6.6 Subdrilling

Subdrill depth is normally 0.2 to 0.4 times the burden. Any subdrilling in excess of this is wasteful and unnecessary. The deeper the subdrill, the greater the confinement, crater angle, and ground vibration. Subdrill charging should be carefully controlled by tape measurement and, if necessary, by backfilling.

When drilling holes adjacent to pit walls, subdrilling should be minimized; in many cases, it can be completely eliminated. To avoid crest fracturing of the lower bench, holes should be placed so that the planned crest of the bench below falls between blastholes (Figure 4). It is better to create poorer digging conditions and rip-to-grade in this area, if necessary.

6.7 Perimeter Blasting

Once production blasting procedures have been optimized, the need for perimeter blasting can be evaluated. In some areas, optimized production blasting may be adequate. In order to evaluate a given area, it is necessary to measure the distance behind the last row of

production holes that the shovel can dig. If this distance is less than the damaged zone distance (Figure 2), a perimeter blast consisting of a buffer row and/or trim row may be required.

The location, spacing, burden, and powder charge for the buffer and trim rows depend on the difference between the measured digging distance and the damaged zone distance for the production blast. Optimizing the buffer and trim row parameters is a trial-and-error process, but the following guidelines can be used as a starting point:

Buffer Row:
- Spacing = 1.0 production spacing
- Burden = 1.0 production burden
- Charge = 0.8 production charge

Trim Row:
- Spacing = 0.5 production spacing
- Burden = 0.8 production burden
- Charge = 0.3 to 0.4 production charge

Perimeter blast layout should always be done from the final wall drop flag line rather than from the free face. A basic pattern for the perimeter blast design above showing spacing relationships, delays, and firing sequences is presented on Figure 5. It is recommended that charge distribution be maximized and wall damage minimized by decking or decoupling the trim row charges as explained below.

6.8 **Charge Distribution**

Several methods can be used to obtain an evenly distributed, low-energy concentration at the pit perimeter. These include decreasing blasthole diameters and spacing, using decoupled charges, decked charges, and low density/low energy ANFO formulations.

Small-diameter drill holes create less damage to final pit walls than do larger holes. Doubling the hole diameter doubles the rupture radius for the same explosive and rock type. The use of small-diameter blastholes also allows the utilization of smaller hole spacings, smaller charge weights, and higher explosive column rise. Thus, smaller-diameter blastholes enable a more even distribution of explosive energy along the pit wall since more holes are used with less energy per hole.

The decoupling method leaves a space between the explosive charge and the borehole. Small-diameter PVC pipe, cardboard tubes, continuous-length shot bags, or continuous-length

slurry explosives within large-diameter blastholes are traditionally used to decouple an explosive charge. A good technique to control blasting is air-layering or decking, which consists of supporting stemming above a chamber of air in the blasthole. When detonated, the explosive expands into the air void and provides the equivalent of higher explosive column rise. The lower the developed borehole pressure, the less overbreak will occur. Likewise, the higher the explosive column rise, the better the fragmentation of the blasthole collar region. Stemming may be supported by plugs (e.g., empty primacord/fuse spools, wood blocks, etc.) lowered to the right position in the hole on lengths of rope.

The decking method alternates short charges with stemming to produce a discontinuous explosive column. In this way it is possible to reduce the high energy concentration and large zones of cratering and fracturing produced by fully charged, large-diameter holes. Each explosive deck can be delayed separately in order to decrease the amount of explosive per delay.

Decoupling and decking are expensive, not only from the standpoint of the additional hardware required (e.g., tubes, liners, plugs, primers, etc.), but also because of the extra labor needed to prepare tube charges and stemming between decks, etc.

The strength of ANFO can be reduced by auguring an inert filler into the ANFO when loading the blastholes. These low-energy mixtures can be economically bulk-loaded and have great potential in control blasting because of the low borehole pressures produced. Low-energy ANFO mixtures can be provided by vendors of explosive products.

Reduction of borehole pressure in the trim row by any of the above means is suggested. By ensuring that the borehole pressure is sufficiently low, crushing around blastholes on the final row can be avoided and backbreak and vibration can be reduced.

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Table 1

Criteria for Observable Blast Damage

Observation	***Conclusion***	***Estimated Peak Particle Velocity (inches/second)***		
		Porphyry	Schist	Dacit
Occasional falling of loose rock from bench faces	No damage	< 5	< 2	< 25
Partially loosened rock falls from faces that would have remained in place if not blasted	Possible damage, but probably acceptable	5 - 15	2 - 10	25 - 50
Portions of bench face fall, loosened rock falls, some fracturing in bench level	Minor blast damage	15 - 25	10 - 15	50 - 75
Backbreak extends into toe, crest of future benches heavily fractured, noticeable increase in fracture intensity on bench and in face, cratering near bench toe, heaved ground and offset on structure	Blast damage	> 25	> 15	> 75

(Modified after Oriard, 1971)
From Savely, 1984

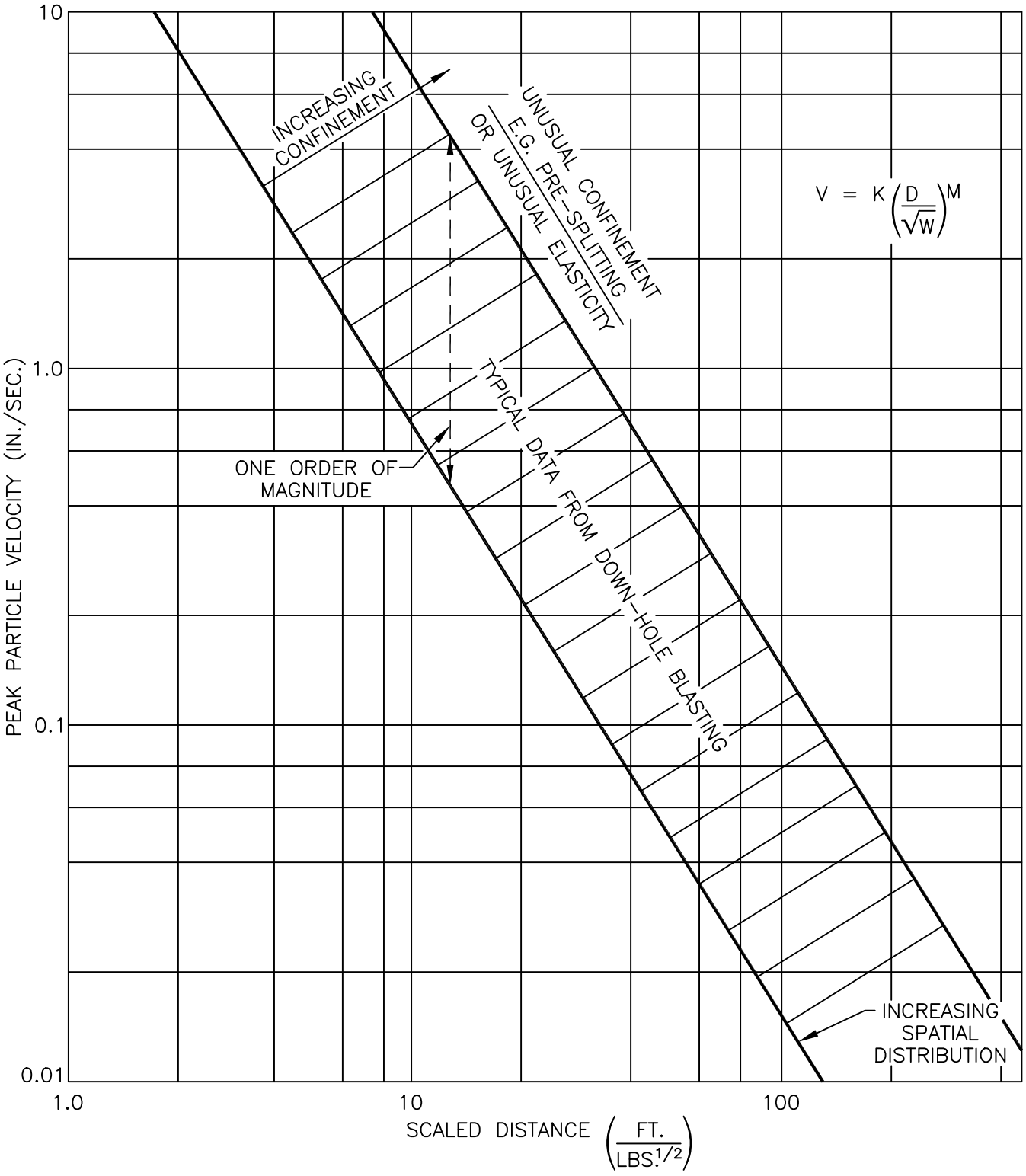


Figure 1
Typical Ranges of Velocity vs. Scaled Distance
for Down-Hole Blasting (Oriard, 1971).

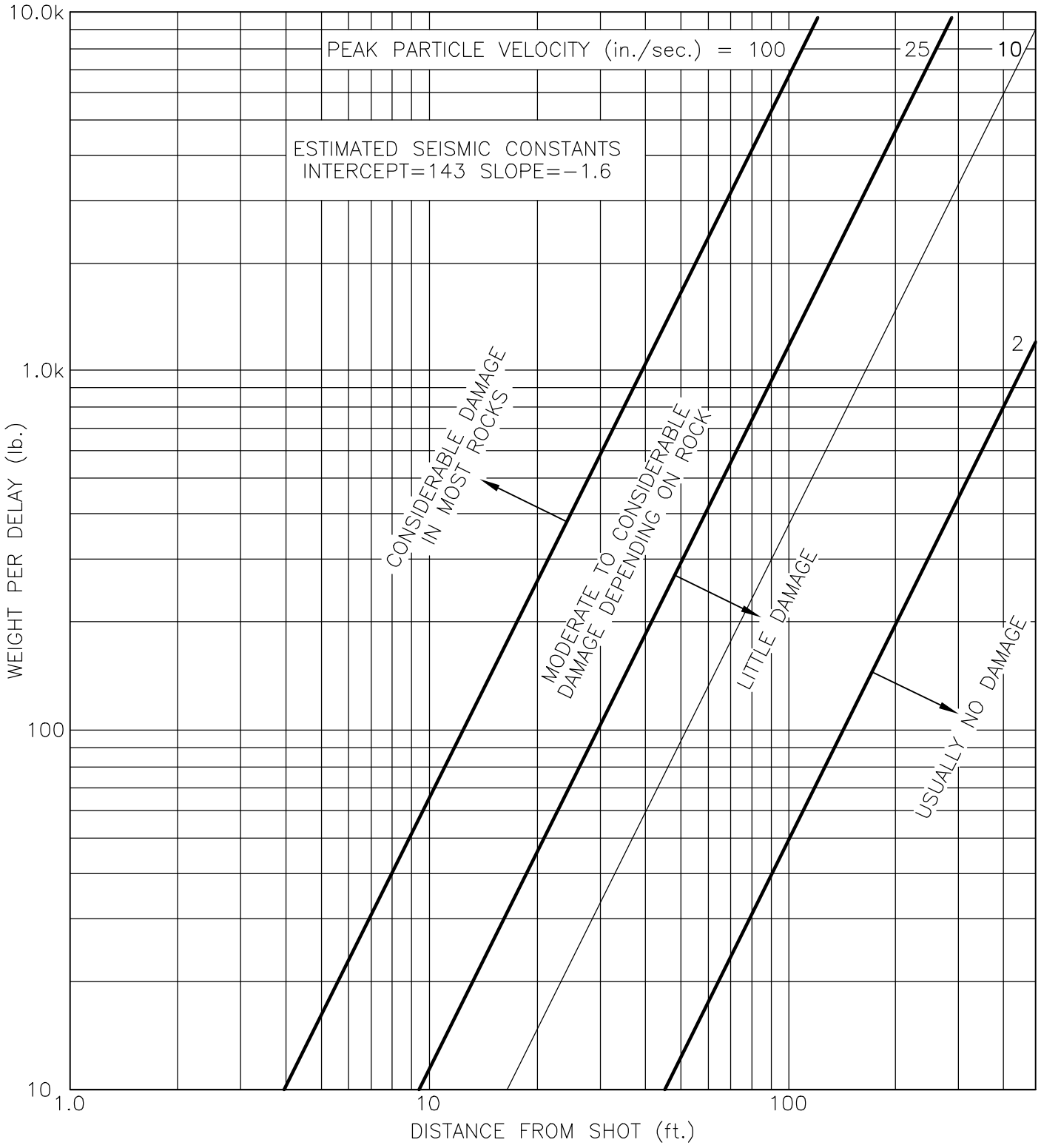
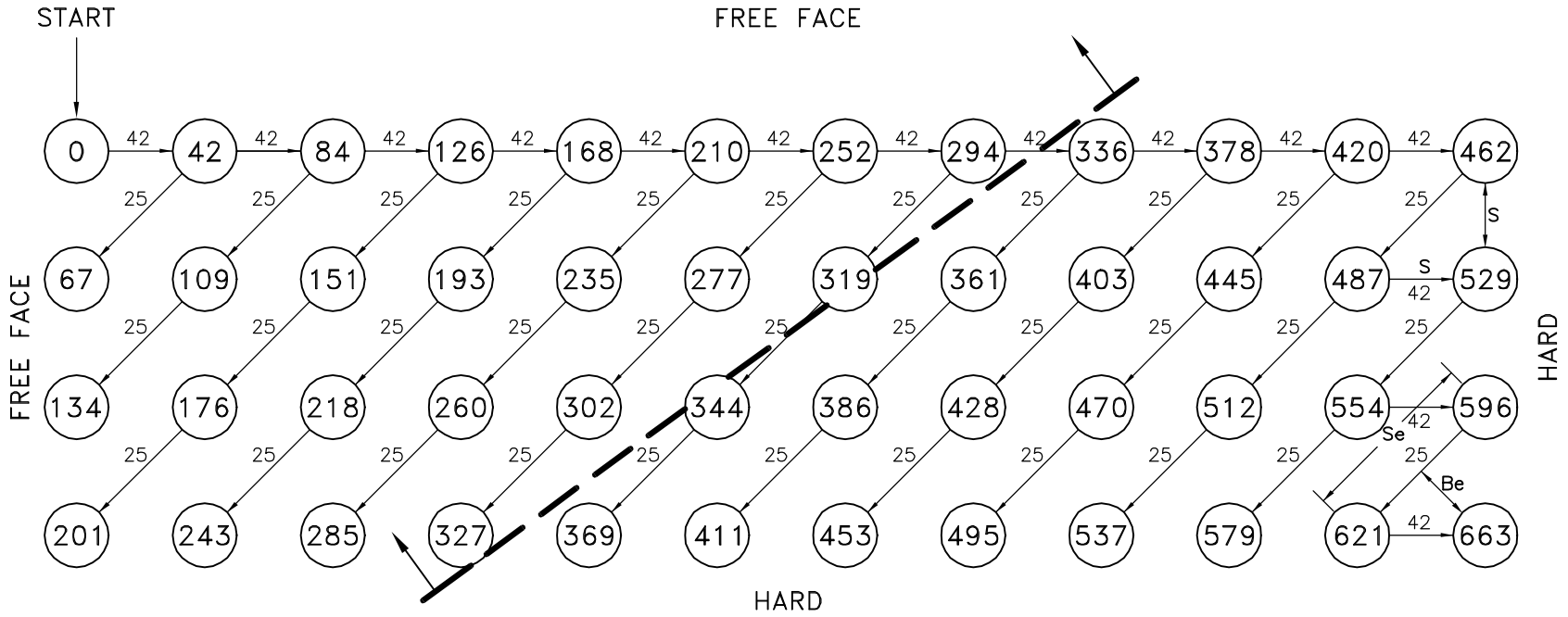


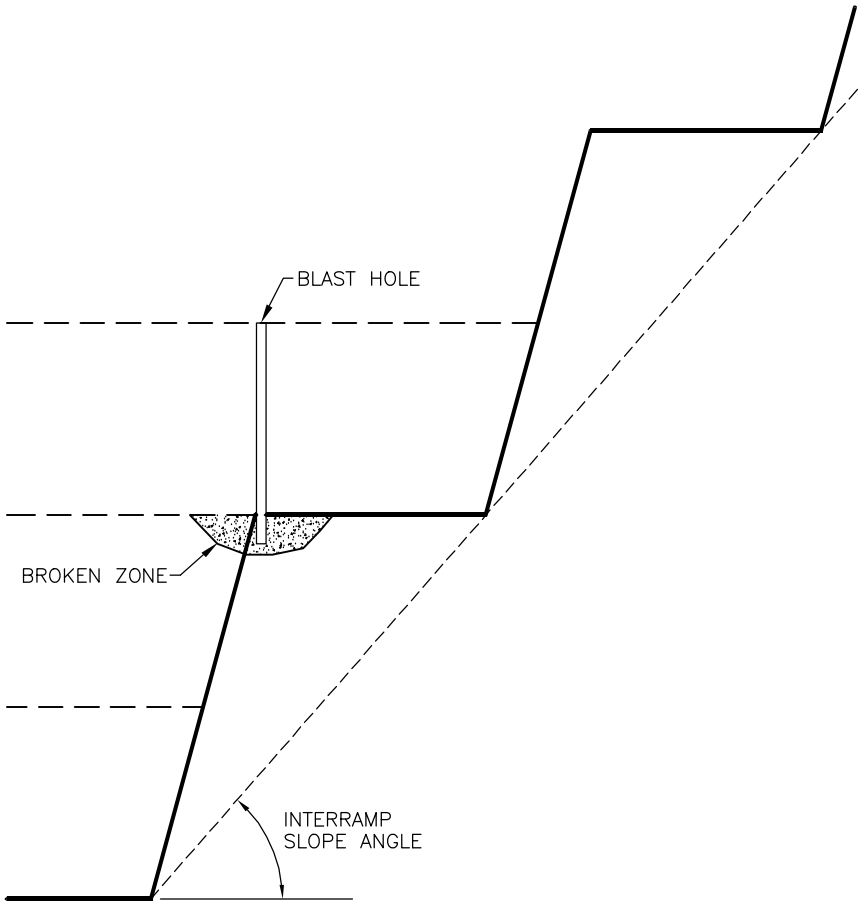
Figure 2
Estimated Damage Zone Distance Plot.



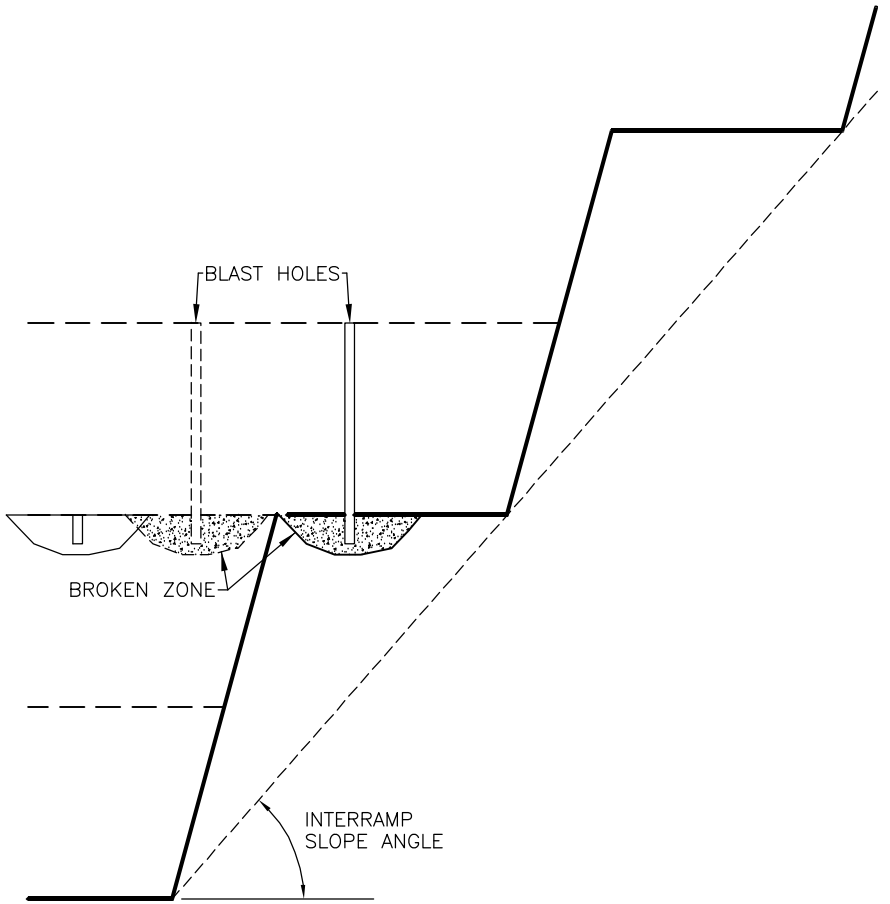
LEGEND

285	Surface Firing Time	S	Layout Spacing
25	Surface Delay	Se	Effective Spacing
———	Movement	Be	Effective Burden

Figure 3
Conventional Square Multiple Row Pattern
25 & 42ms Surface Delays With 200–400ms Down Hole Delays
(After Ensign Bickford)

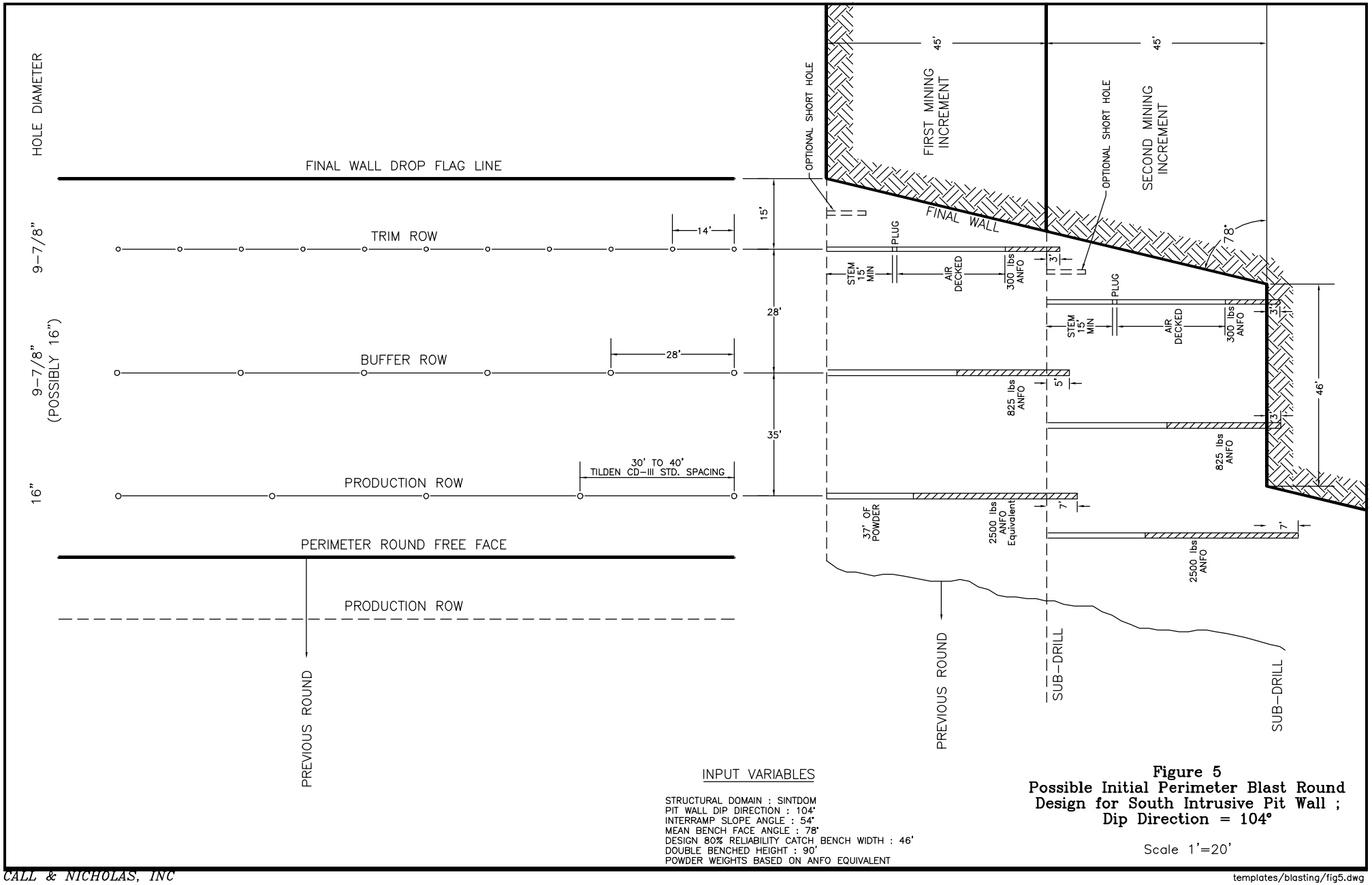


WORST POSITION
(Blast Hole at Bench Crest)



BEST POSITION
(Bench Crest Between Blast Holes)

Figure 4
Schematic Layout of Blast Holes Along Final Wall.

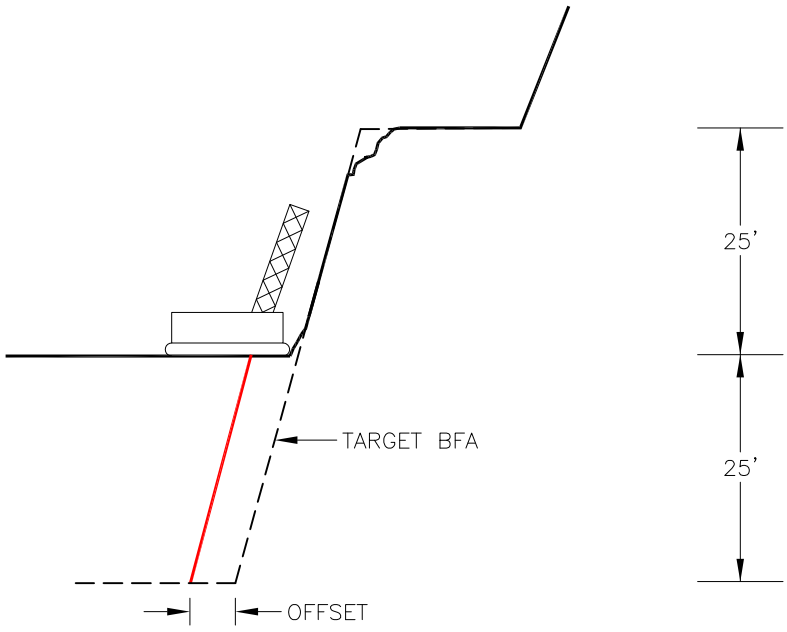


INPUT VARIABLES

STRUCTURAL DOMAIN : SINTDOM
PIT WALL DIP DIRECTION : 104°
INTERRAMP SLOPE ANGLE : 54°
MEAN BENCH FACE ANGLE : 78°
DESIGN 80% RELIABILITY CATCH BENCH WIDTH : 46'
DOUBLE BENCHED HEIGHT : 90'
POWDER WEIGHTS BASED ON ANFO EQUIVALENT

Figure 5
Possible Initial Perimeter Blast Round Design for South Intrusive Pit Wall ; Dip Direction = 104°

Scale 1'=20'





SCALE 0 5 10 METERS
(1:500)

LEGEND

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

DRAWN	DATE	REVISED
LMC	04/11	9/6/2015 3:20 PM

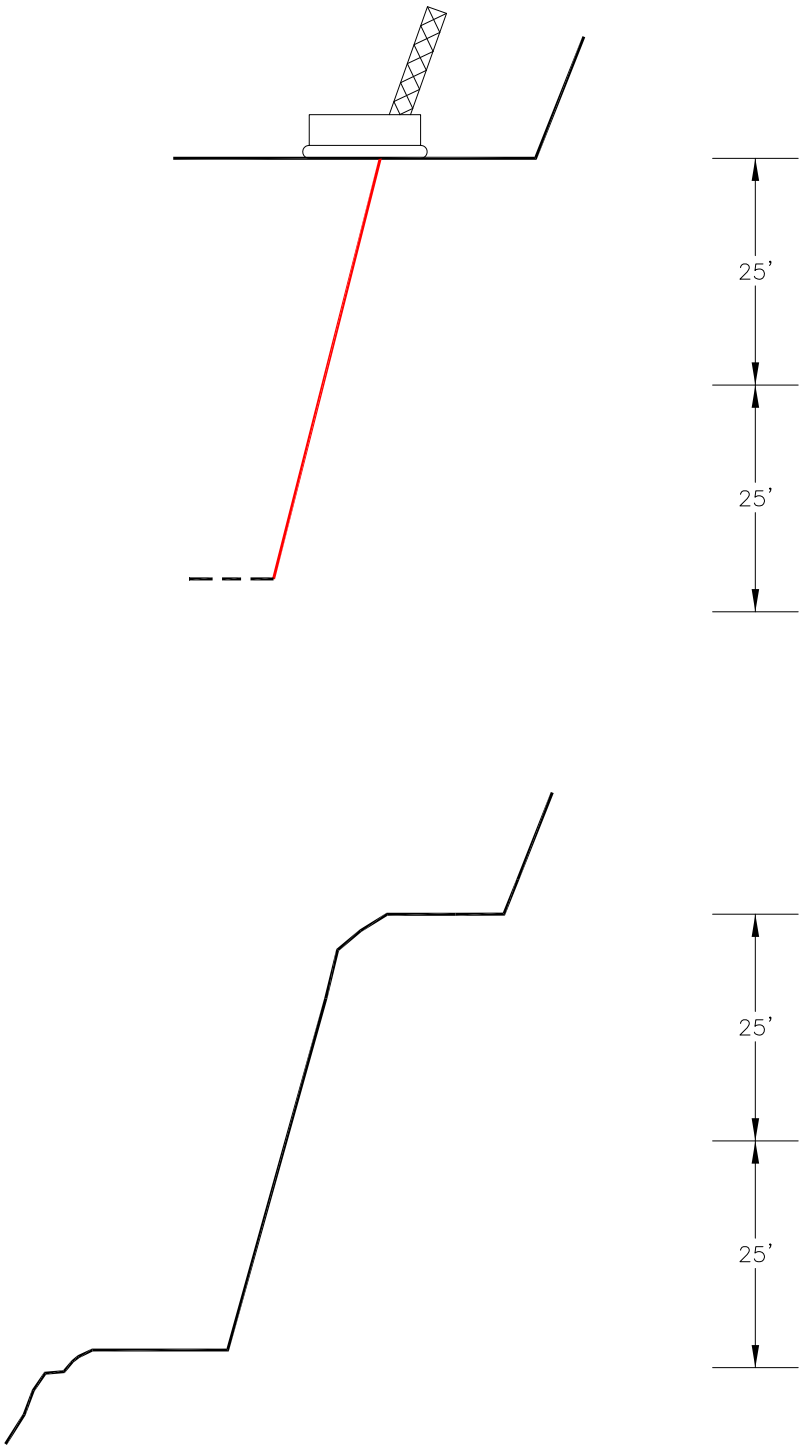
\2015\NAU_STUDY\REPORT\APPENDIX B – CONTROLLED BLASTING\FIG 6 – DOUBLE PRESPLIT 1.DWG

OFFSET IN SINGLE- BENCH PRE-SPLITTING

CRIPPLE CREEK & VICTOR

SCALE 1:500

FIGURE 6



LEGEND

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

DOUBLE-BENCH PRE-SPLITTING NO OFFSET

CRIPPLE CREEK & VICTOR

DRAWN	DATE	REVISED	SCALE	
LMC	04/11	11/5/2015 10:28 AM	1:500	FIGURE 7

\2015\NAU_STUDY\REPORT\APPENDIX B – CONTROLLED BLASTING\FIG 7 – FULL DOUBLE PRESPLIT 2.DWG

APPENDIX C

2015 GEOTECHNICAL BLOCK MODEL REPORT

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MEMORANDUM

To: Erik Munroe \ AngloGold Ashanti Corporation
Doug White \ AngloGold Ashanti Corporation

From: Lance Bacon \ Call & Nicholas, Inc.
Scott Cylwik \ Call & Nicholas, Inc.
Ross Barkley \ Call & Nicholas, Inc.

Date: 11 May 2015

Subject: 2015 Geotechnical Block Model

1.0 INTRODUCTION

At the request of Mr. Erik Munroe of the AngloGold Ashanti (Colorado) Corporation, Call & Nicholas, Inc. (CNI) has created a three-dimensional block model estimate of rock quality designation (RQD) and the rock mass quality parameter Q' for the Cripple Creek (CC&V) open-pit mine operation. All drill-hole and block modeling operations were performed using MineSight® mine planning software at CNI's office in Tucson, Arizona. The models will be used by the CC&V mine planning and geology departments in short- and long-term mine planning, and by the geotechnical department and CNI for geotechnical analysis.

The process used to create the model and plots summarizing the model are presented within this report.

1.1 Data Sources

CC&V mine personnel provided geologic, drill-hole, and mine design data in the form of digital MineSight files that were used to develop the block models.

CNI was provided with Excel files (CC&V_RQD_2-23.zip) containing the collar, down hole survey, geology and geomechanical data. The drill-hole data loaded to MineSight included all geotechnical drill-hole information such as RQD and other descriptive geomechanical characteristics.

A total of 413 drill holes with RQD data were included in the drill-hole files out of a total database of 425 drill holes. CNI generated basic statistics on the drill holes but made no attempt to verify or otherwise reconcile the drill-hole database.

Three-dimensional lithology was provided to CNI in the form of MineSight 3D wireframes (CC&V_Geol_wireframes.zip) that were coded to a block model. These rock types form the basis of the logic used to develop an RQD estimation strategy.

The final pit designs (03-04-13-03 CR01 Design and WHEX Design 8-4-14) and original topography were also provided to CNI for use in determining the extent of the RQD estimate needed.

2.0 DRILL-HOLE DATA

Drill-hole data in the form of Excel files were provided in February 2015. These files were then compiled and loaded into MineSight's drill-hole data files for use with all the MineSight series of drill-hole operation programs.

A total of 425 drill holes were contained in the drill-hole files out of which 413 holes contained RQD data and 255 holes contained additional geomechanical data. One-hundred and ninety drill holes contained the Q' parameter. Once drill-hole data were loaded in the MineSight interface, the drill holes could be viewed in three dimensions, statistics run, and calculations performed to develop associations that determined rock quality.

2.1 Drill-Hole Descriptive Statistics

Statistical programs were run in MineSight on the drill-hole file data after all percentage geomechanical data were capped at 100 percent. Filters were set to access only those holes with RQD data. As in any other three-dimensional block model estimation, controlling factors that limit or constrain the estimate must be found. Statistical analyses were run on rock type to determine if there was an association that controlled the deposit's RQD based on the rock type.

2.1.1 Rock Type

The Cripple Creek deposit is primarily made up of phonolite, breccia, Precambrian granodiorite, and lamprophyre. Drill-hole intervals were tagged with the rock type that occurs in the three-dimensional block model so statistics could be run on the RQD by the different rock

types. Table 2-1 shows basic RQD statistics on drill-hole data for each model rock type. Figure 2-1 shows the cumulative distribution of RQD by each rock type.

Each of the rock types that occur in the geologic model were grouped into rock groups to simplify the RQD estimation process. Table 2-2 shows the rock types in the geologic block model and the rock groups that were used during the estimation process. For this study, the lamprophyre dikes were added to the breccia rock group because they differ in rock quality from the lamprophyre pipe. Figure 2-2 shows some of the geomechanical parameters by rock group.

2.1.2 Q'

One-hundred and ninety drill holes contained the necessary data for calculation of the rock mass parameter Q'. The data needed to calculate Q' are RQD, Jr (joint roughness), Jn (joint set number), and Ja (joint alteration number). While the parameters Jr, Jn, and Ja were not directly collected in the drill logs, information of sufficient detail regarding joint roughness and alteration was collected to allow for conversion to the Q' parameters. The conversion scale utilized for the estimation of Q' is shown in Table 2-3 and Q' was calculated using the following formula:

$$Q' = \frac{RQD}{Jn} \times \frac{Jr}{Ja}$$

2.2 Drill-Hole Composites

Drill-hole RQD composites were calculated using a 15-foot fixed length composite. It has been found that compositing over smaller intervals tends to help retain any low drill hole RQD in the block model estimate. Using larger composites tends to smooth the RQD distribution in the block model estimate, pushing values closer to the mean value of RQD.

The log of Q' was calculated and placed in the drill-hole item QPLOG and then composited using the same logic as for RQD discussed above.

2.2.1 Variography

Variography of composite data was run to determine if any anisotropy existed in the composited drill-hole data. Correlograms were used to determine search ranges for the composited data and identify any potential anisotropy. Additional correlograms were calculated

considering individual rock types and rock type groups, and although search ranges were confirmed, no correlograms were found to identify anisotropy. It was therefore decided to use a 3D spherical search since no dominant anisotropy could be found.

To determine an appropriate search distance to use with a spherical search, median directional variograms were generated. The variograms indicated that distances in excess of 700 feet could be used. For the estimation of RQD, 700 feet was used for the large search and overwritten by a smaller 500-foot search which represented approximately 75 percent of the variogram range. The search parameters will be discussed further in Chapter 3.

3.0 BLOCK MODEL ESTIMATION

Three-dimensional geologic block model wireframes were provided by the CC&V geology department. The block model rock type was coded to a block model with the same origin and extent as the CC&V model to perform the RQD estimate.

Block model items were initialized in this block model for RQD estimation to store the RQD value, nearest neighbor RQD value, closest distance to the nearest composite, number of composites used, number of holes used, and average distance for all composites used.

3.1 Rock Groups

It is preferable to group like rock types together into rock groups to get a more complete RQD estimation. Rock type groups were therefore used to control the RQD estimation instead of the individual resource model rock types. There were so many rock types in the resource model that if the RQD search was confined to within each individual rock type, many blocks would have had little or no data available.

After rock group codes were assigned to the model blocks, the codes from the block model were assigned to the composite file intervals. Having the composites coded with the block model rock type groups allows a restriction to be used in the estimation process that matches blocks of a given rock type group with composites of that same group (geologic matching).

3.2 Estimation Techniques

Two techniques were used for the block model RQD estimation: inverse distance weighting (IDW) and nearest neighbor. The two techniques can be run at the same time, and the nearest neighbor provides a good estimate of how well other estimation techniques are performing.

3.2.1 Inverse Distance Weighting Estimate

It has been found on other projects that an IDW method of block model RQD estimation works well. CNI decided to use the IDW to the third power estimation technique because it has been proven to better retain the lower-range RQD distribution. This helps when assessing geotechnical pit slope stability.

3.2.2 Nearest Neighbor Estimate

The polygonal or nearest neighbor estimate was run along with the inverse distance estimate. Because the nearest neighbor estimate is considered globally unbiased, it is used to compare results from the inverse distance interpolation technique. The mean value of the nearest neighbor estimate should be very similar to the mean value of the inverse distance estimate. Using a nearest neighbor estimation technique provides a very good local RQD estimation because it uses the closest composite. As the distance increases between drill-hole composites, the nearest neighbor estimate does not perform as well because it does not extrapolate data well between data points such as drill-hole composites.

3.3 Block Model RQD Estimate

The IDW estimation technique was used to estimate the RQD into the block model. It has been found that an IDW estimate and smaller composite size tends to retain the distribution of the composites for the low and high range of the distribution. Kriging, although better visually, tends to smooth the distribution to the mid-range of the RQD distribution. For geotechnical studies, it is critical to identify and retain any low rock quality areas in the block model estimate.

For geotechnical analysis, it is preferable to have an RQD estimate that extends beyond the limits of the final designed pit. Drill-hole data density is variable, with typically lower density of drilling as limits of the final pit are reached. There are also areas within the limit of

the final pit that have a low density of drilling data. Figures 3-1 and 3-2 show the final pit plans with rock types projected to the surface along with the drill-hole pierces on the pit. Only holes that contain RQD values were used to display the pierce points. There are several areas within the ultimate pit limits that have limited drill-hole coverage. Figure 3-3 shows the final pits with areas estimated by each of the three estimation runs. Areas where the first run using the large search radius highlights areas where there is a low density of drilling.

Because of the low drilling density in some areas, a two-pass system of RQD estimation was developed. The first pass makes use of a larger search distance to fill in blocks that would not be covered in subsequent runs.

This first pass also does not require that the block model rock group code match the composite rock group code (no geologic matching). The effect of the first-pass estimation run is to fill in the model as much as possible, and then subsequent runs overwrite the first pass with a more restricted search and require that the same block rock group codes match the composite codes (geologic matching). This allows runs after the first pass to provide a more restrictive local estimation that honors the geologic rock groups.

A final RQD estimation run was used that made use of indicators to determine the probability of any particular block being either high or low RQD. Indicators for a final run can be used in order to retain the low and high RQD seen in the drill-hole composites.

Table 3-1 shows details of each run and composite parameters used. All runs used the IDW to the third power with varying composite selection to interpolate a block. Search ranges for the first pass used 100 percent of the variogram ranges, and search distances for subsequent runs used 75 percent of the variogram ranges. Composite selection was set so that the large search estimate only needed one drill hole to produce an RQD estimate, whereas at least two drill holes were required to produce an RQD estimate for the smaller search estimate.

Although the two-pass system of RQD estimation allows for filling the block model with an RQD value by using the first-pass large search range, there are still areas of low-density drilling within the pit limits where no estimate was produced (southern and northern portions of the Cresson final pit). This system is not intended to completely fill the block model with an RQD estimate but rather fill the model with an estimate within reasonable geostatistical limitations.

Figure 3-4 shows the block model IDW RQD estimate distribution along with the composite distribution. The mean RQD value of the IDW estimate is very near that of the mean RQD value of the drill-hole composites. Figures 3-5 and 3-6 show the RQD estimates as projected to the final pit surfaces.

The RQD estimate should be updated when additional drilling data are available. As new data are added, it is possible the estimation technique or rock type groups might have to be changed to better fit the data. This would probably take a large increase in the number of drill holes with RQD data.

Any significant changes to the rock type interpretation in the block model would require that the RQD estimate be re-estimated so it correctly matches the rock type groups. The same holds true for any additional interpretation of geology such as alteration assemblages that may impact rock quality. Basic statistical analyses should be run to determine if rock quality changes can be attributed to the addition or reinterpretation of geologic features.

3.4 Block Model Q' Estimate

The block model estimate of Q' was coded into the block model in much the same way as RQD using a large search distance first pass followed by a second pass with a more restrictive search and composite selection. No indicator run was used in the Q' estimate. The log of Q' was calculated and placed in the drill hole item QPLOG, composited, and estimated into the block model item QBLOC, and then converted back to Q' in the block model item QLOG by raising 10 to the power of QBLOC. Figure 3-7 shows the Q' composites compared to the Q' block model estimate and Figure 3-8 shows Q´ on the final pits.

3.5 Block Model Items

The final coded items in the block model that are pertinent are as follows:

RQDID – 3D block model estimate of RQD

QBLOC – 3D block model estimate of log of Q´

QLOG – QBLOC converted to Q´

4.0 CONCLUSIONS AND RECOMMENDATIONS

Block models of RQD and Q' have been generated with the latest 2015 data. The models may be used by CC&V mine planning and geology departments in short- and long-term mine planning, and by the geotechnical department and CNI for geotechnical analysis. Some areas are missing blocks or have blocks that were estimated based on only a single drill hole (Figure 3-2). Additional core holes should be drilled in these areas.

The RQD block model has been transferred to CC&V staff as MineSight files that can be loaded into the mine planning model. The MineSight project control file (PCF) name is crck10.dat and the block model file is crck15.215. The primary item to be used from the model is designated RQDID, which is the inverse distance cubed estimate RQD value.

All RQD coding and interpolation were accomplished using multiruns within the MineSight interface using MineSight programs during the RQD estimation process.

Table 2.1
Cripple Creek Drill Hole RQD Statistics

Rock Type	Description	Total Samples	Total Length (ft.)	Number Assayed	Sampled Length (ft.)	Min	Mean	Max	St. Dev	Variance	CV
12	Syenite	587.0	5,172.0	582.0	4,964.0	0	68.7	100	27.3	747.7	0.4
22	Syenite	34.0	289.0	33.0	239.0	0	65.4	100	26.0	674.1	0.4
23	Syenite	309.0	3,018.0	296.0	2,105.0	0	58.7	100	30.9	956.1	0.53
31	Porphyritic phonolite with K-spar	2,447.0	20,391.0	2,381.0	16,143.0	0	65.3	100	25.5	651.3	0.39
33	Porphyritic phonolite with K-spar	240.0	1,917.5	238.0	1,912.0	0	56.4	100	26.4	696.7	0.47
35	Porphyritic phonolite with K-spar	8.0	97.5	7.0	47.5	0	32.4	73	29.6	874.9	0.91
40	Hydrothermal Breccia	676.0	5,558.5	650.0	4,496.5	0	61.5	100	32.8	1075.9	0.53
41	Hydrothermal Breccia	60.0	342.0	60.0	342.0	0	31.6	90	31.2	971.7	0.99
51	CC Breccia	5,042.0	46,617.0	4,734.0	32,454.2	0	64.1	100	28.0	781.8	0.44
63	Pre-Cambrian granodiorite	20.0	194.0	20.0	194.0	72	83.9	95	7.4	55.2	0.09
84	Lamprophyre-matrix breccia	46.0	409.0	45.0	359.0	0	64.8	100	31.3	977.5	0.48
85	Lamprophyre-matrix breccia	23.0	973.0	21.0	173.0	16	66.0	96	16.1	258.3	0.24
Total		9,492.0	84,978.5	9,067.0	63,429.2	0	63.7	100	28.2	795.3	0.44

Table 2-2

Cripple Creek Rock Types and Rock Groups

Wireframes	Code	Description	RKGRP	RKGRP	RKGRP %
TTD	7	Trachydolerate	Trachydolorite	1	0.02
TTD ISABELLA flt					
TSY 1	12	Syenite	Phonolite	2	6.91
TPHA 1	22				
TPHA 2	23				
TPHA 3 FAULT					
TPHK 1	31	Porphyritic phonolite with K-spar			
TPHK 2	32				
TPHK 3	33				
TPHK 4	34				
TPHK 5	35				
THBX	40	Hydrothermal Breccia	Breccia	3	36.57
THBX Collapse	41				
TBX	51	CC Breccia			
TLBX 1	84	Lamprophyre-matrix breccia (Dikes)			
PC	63	Pre-Cambrian granodiorite	PC	4	56.41
TLBX 2	85	Lamprophyre-matrix breccia (Pipe)	Lamprophyre	5	0.10
TLBX 3 FAULT					

Table 2-3

Cripple Creek Drill Hole Jr, Ja, and Jn

DH JR	Jr
1	1
2	
3	2
4	3
5	3.5
6	
7	
8	4
9	
10	

DH JA	Ja
Clay	4.0
Fresh	1.0
Healed	1.0
Open	1.0
Oxide	2.0
Sandy	3.0
Slick	4.0
Weathered	2.0

RQD	Jn
0-20	15
20-60	12
60-100	9

Table 3-1

Block Model Estimation Parameters

Estimation Run	Search Radius (feet)	Composite Selection			Geologic Matching
		Minimum	Maximum	No. per Hole	
Large Search	700	2	12	1	No
Small Search	500	4	12	3	Yes
Indicator	300	2	12	1	Yes

Figure 2-1
Drill Hole RQD

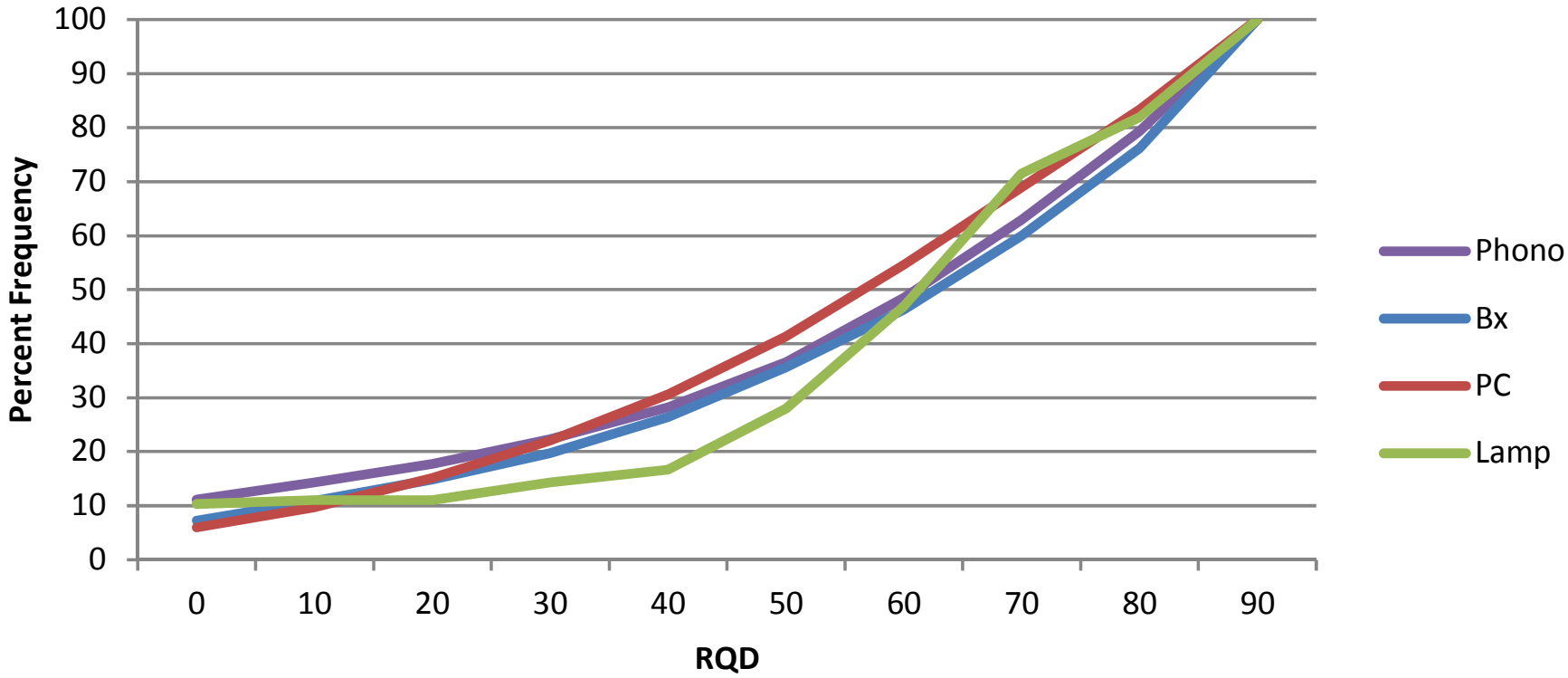
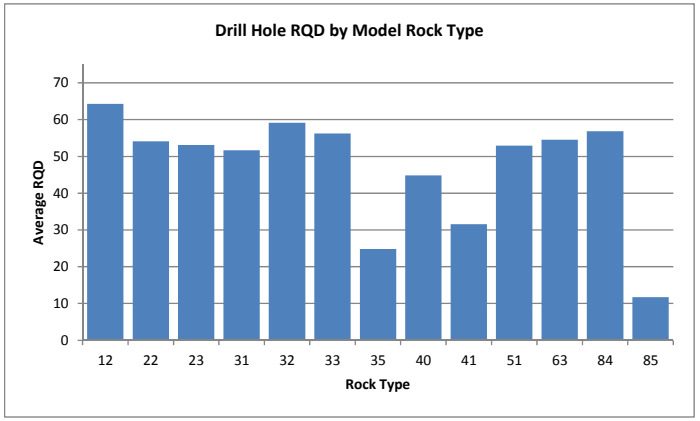
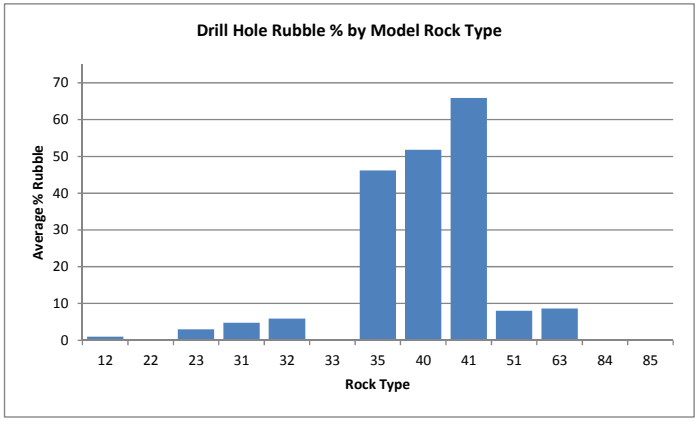
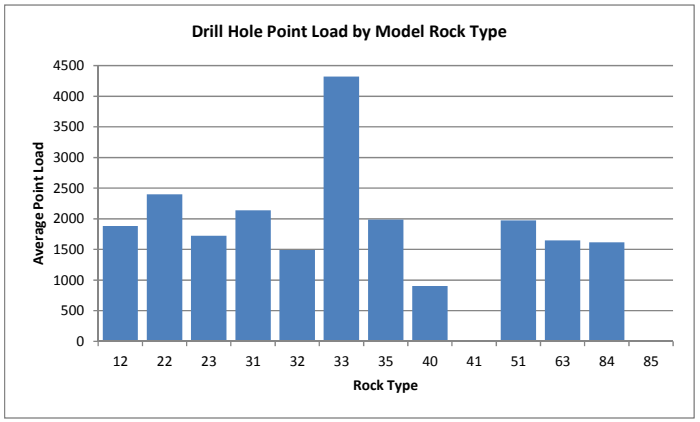
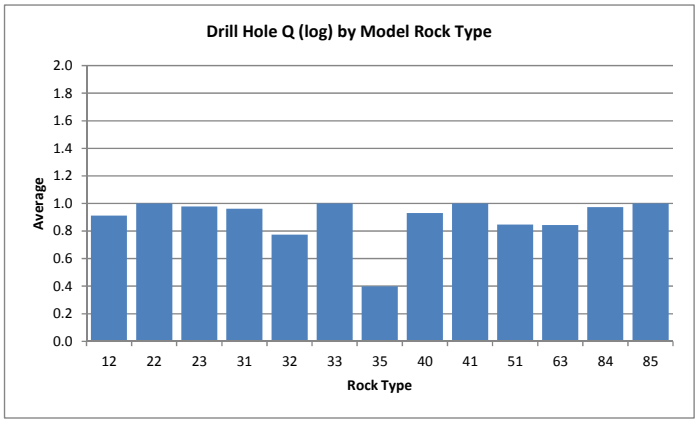


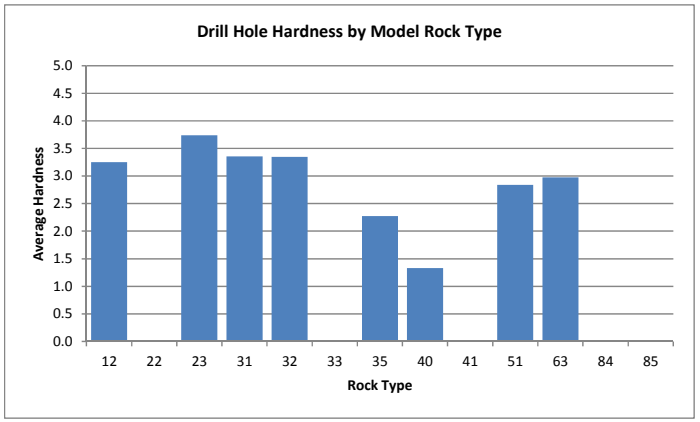
Figure 2-2
Geomechanical Parameters by Rock Type



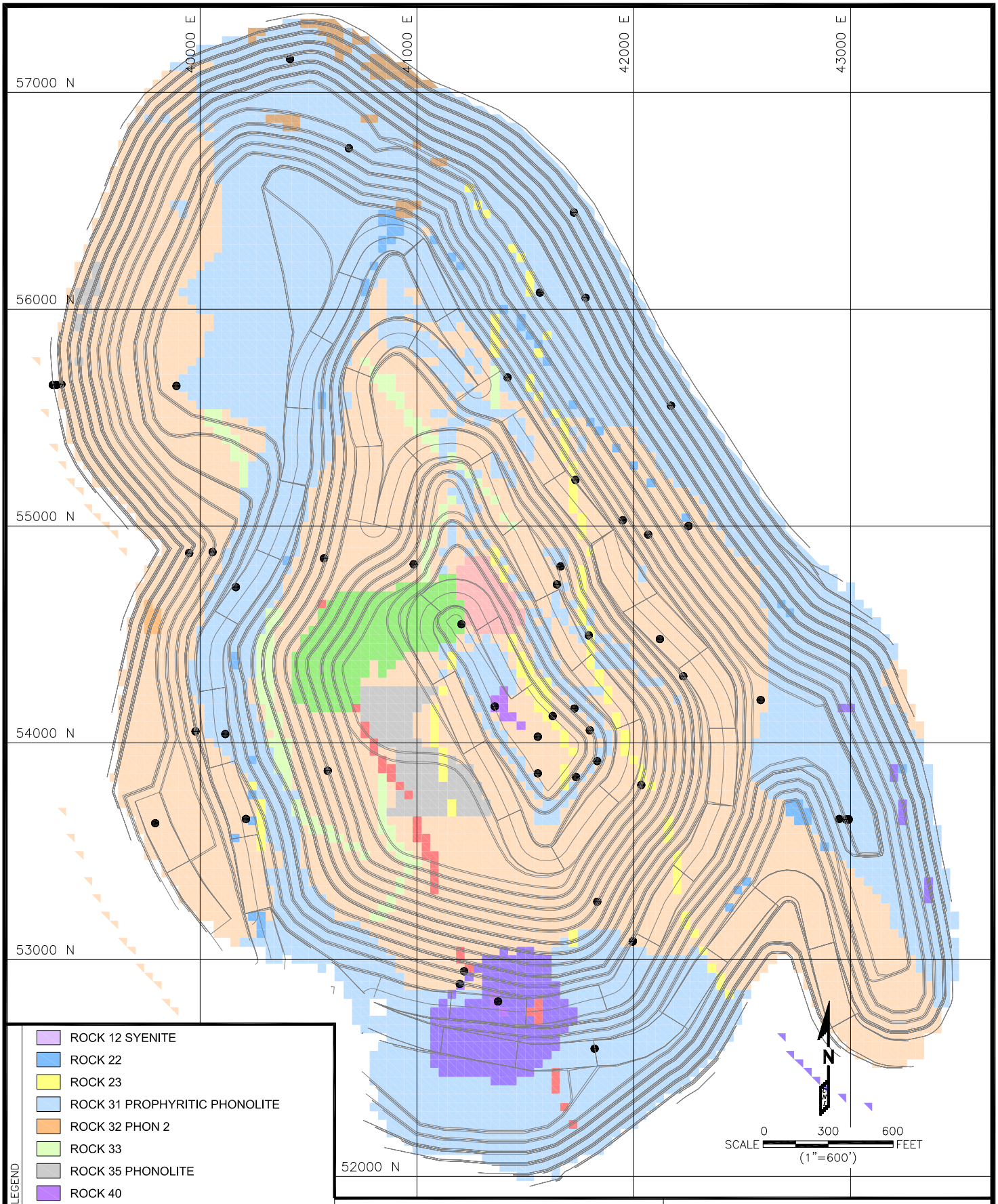








TSY 1	12	Syenite
TPHA 1	22	Syenite
TPHA 2	23	Syenite
TPHK 1	31	Porphyritic phonolite with K-spar
TPHK 2	32	Porphyritic phonolite with K-spar
TPHK 3	33	Porphyritic phonolite with K-spar
TPHK 5	35	Porphyritic phonolite with K-spar
THBX	40	Hydrothermal Breccia
THBX Collapse	41	Collapse Breccia
TBX	51	CC Breccia
PC	63	Pre-Cambrian granodiorite
TLBX 1	84	Lamprophyre-matrix breccia
TLBX 2	85	Lamprophyre-matrix breccia



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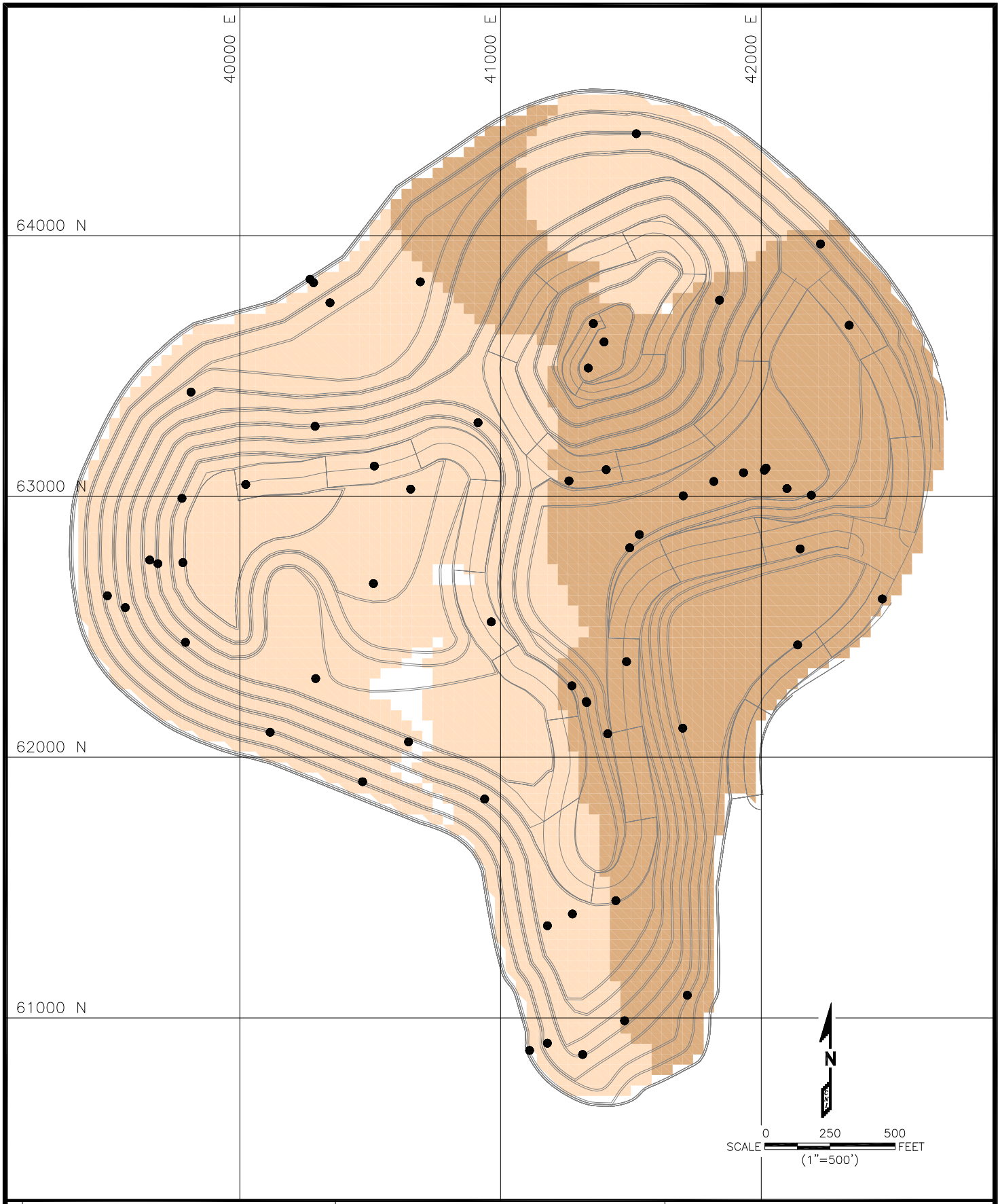
TUCSON, ARIZONA USA

CRESSON FINAL PIT PLAN WITH ROCK TYPES AND PIERCE POINTS

AGA-CCV

DRAWN	DATE	REVISED	SCALE	
LMC	04/15	5/11/2015 3:03 PM	1"=600'	FIGURE 3-1

\2015\REPORTS\MODELING\FIG3-1 – CRES_PIERCE.DWG



LEGEND

- ROCK 51 CRIPPLE CREEK BRECCIA
- ROCK 63 PRECAMBRIAN GRANITE
- RQD PIERCE POINTS

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DRAWN	DATE	REVISED
LMC	04/15	5/11/2015 3:05 PM

\2015\REPORTS\MODELING\FIG3-2 – WHEX_PIERCE.DWG

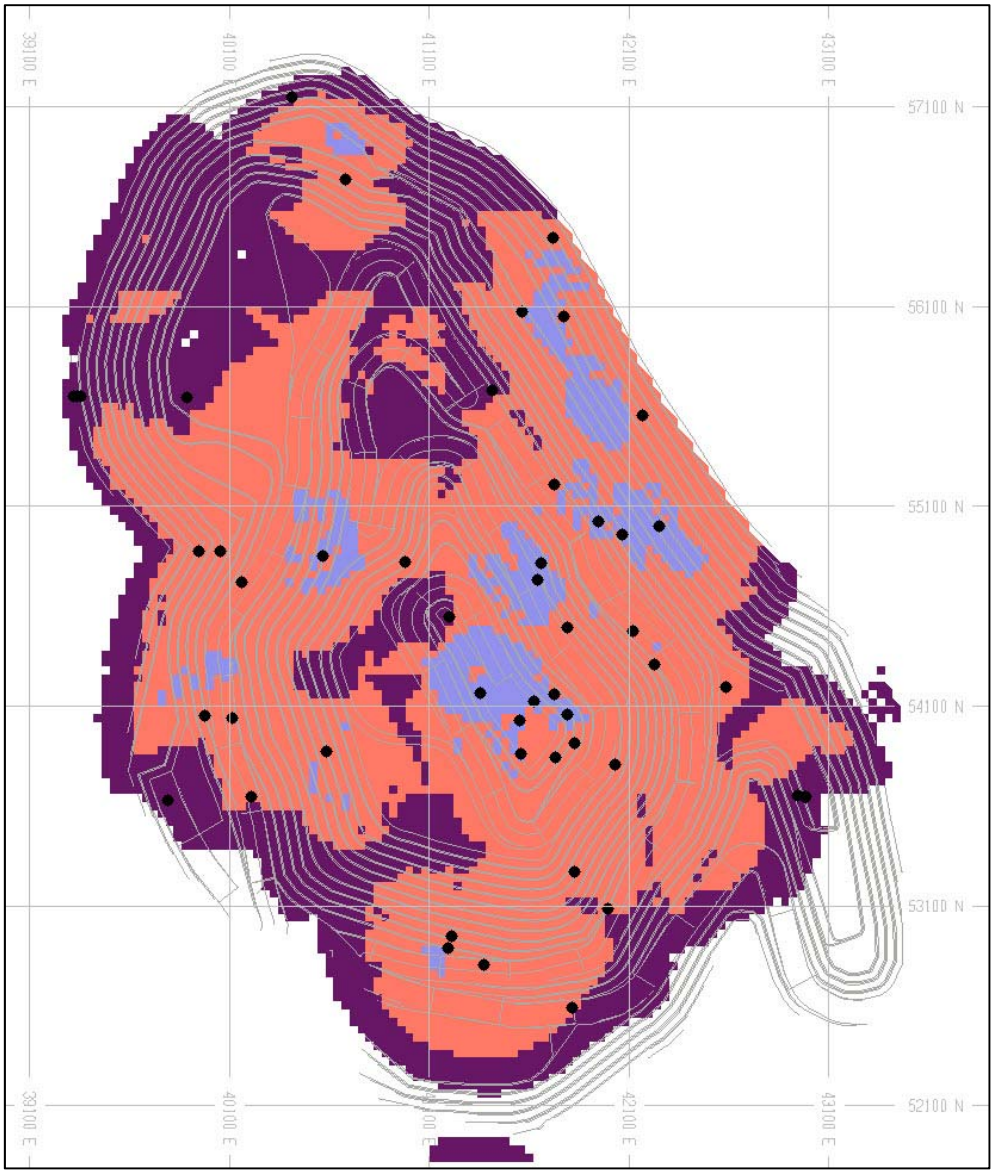
WHEX FINAL PIT PLAN WITH ROCK TYPES AND PIERCE POINTS

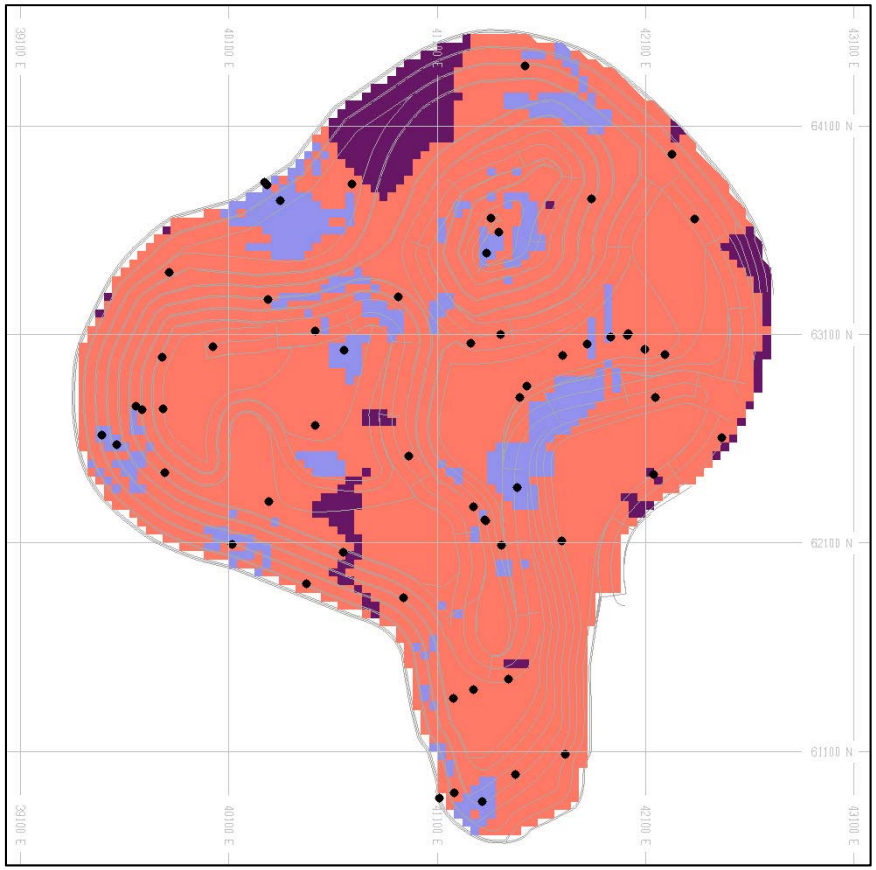
AGA-CCV

SCALE 1"=500'

FIGURE 3-2

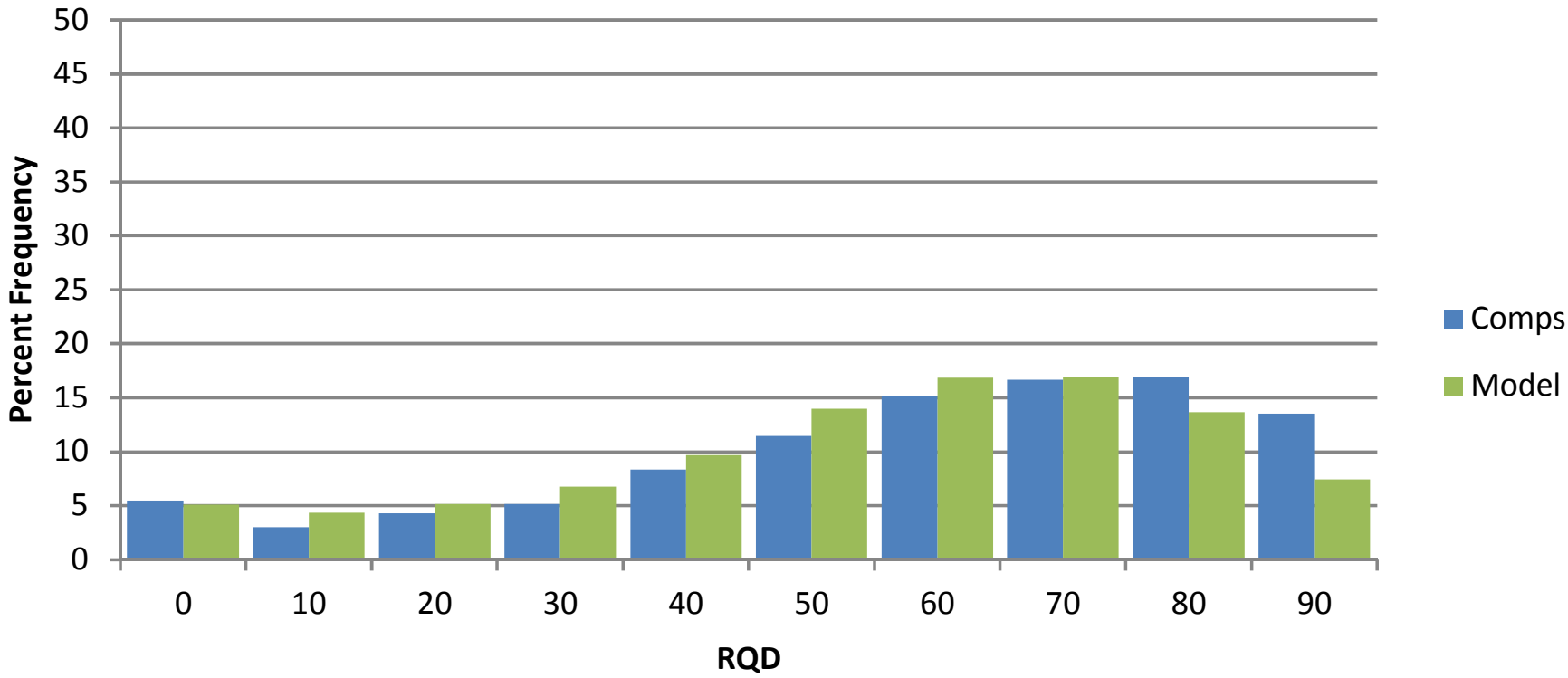
Figure 3-3
Estimation Run on Final Pits
With RQD Drill Hole Pierces

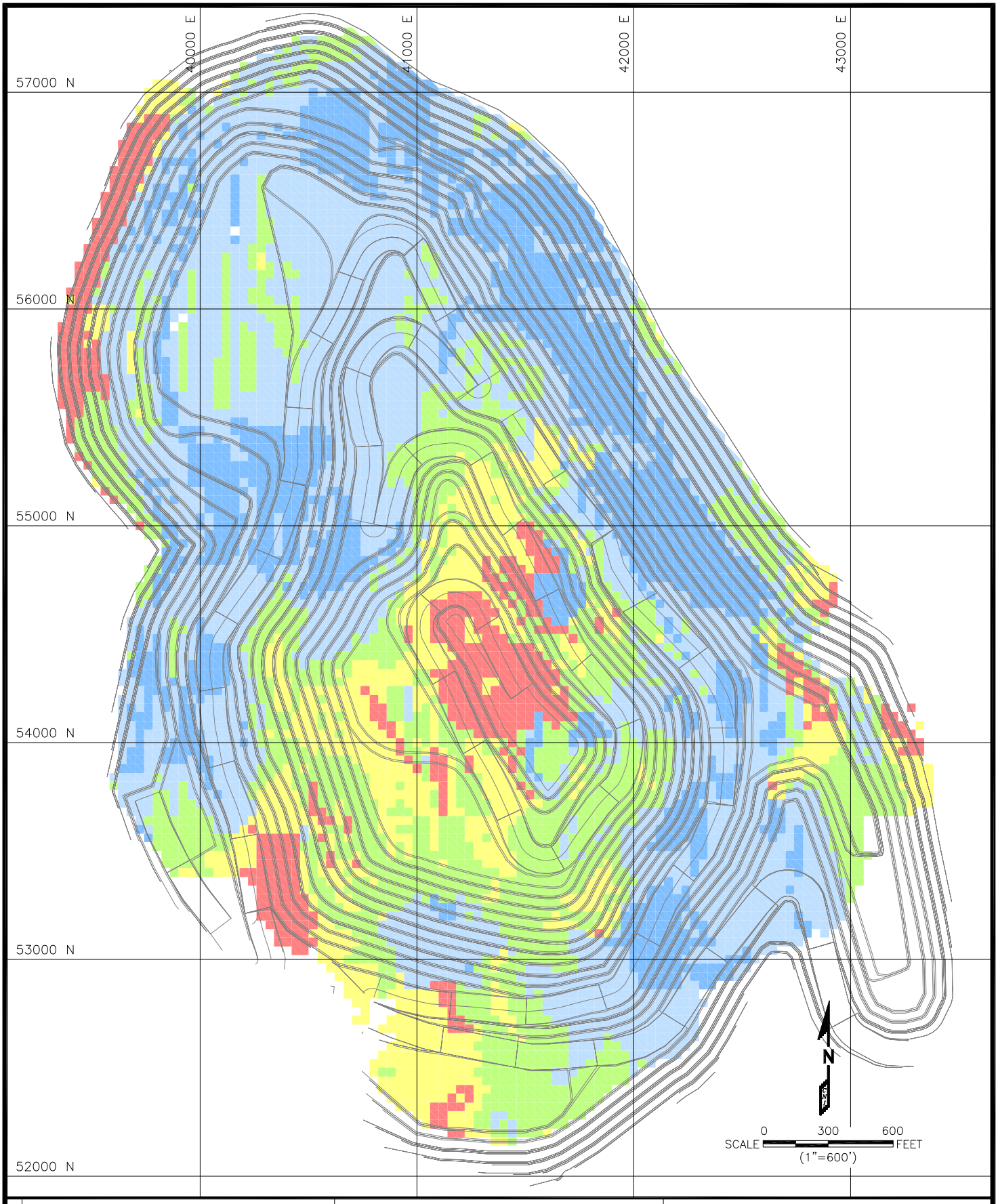




First Run – Large Search
Second Run – Smaller Search
Third Run - Indicator

Figure 3-Π
Cripple Creek RQD





LEGEND

- 0-20 RQD
- 20-40 RQD
- 40-60 RQD
- 60-80 RQD
- 80-100 RQD

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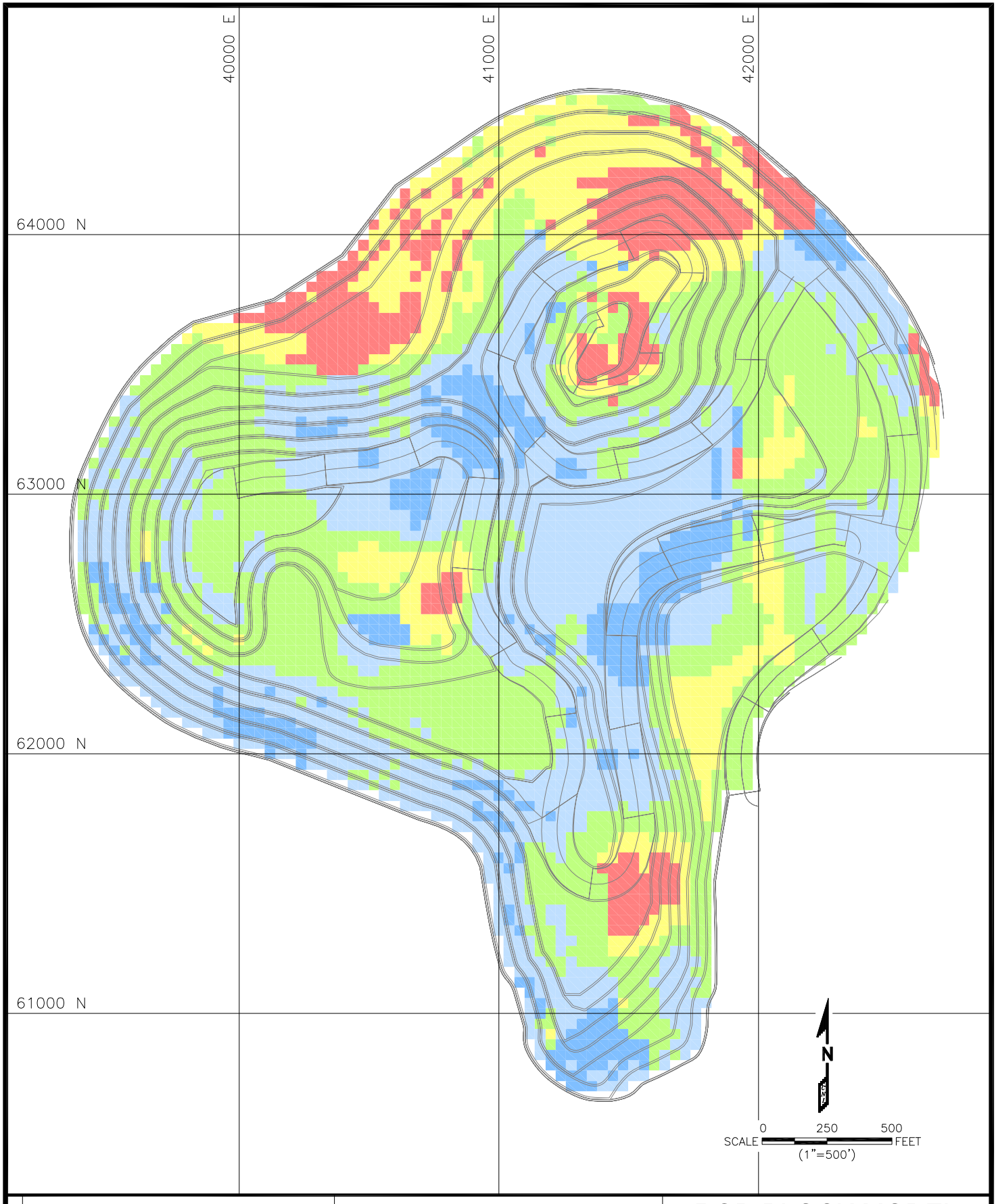
\2015\REPORTS\MODELING\FIG3-5 - CRESSON_RQD.DWG

RQD BLOCK MODEL PROJECTED ONTO CRESSON DESIGN

AGA-CCV

SCALE 1"=600'

FIGURE 3-5



LEGEND

- 0-20 RQD
- 20-40 RQD
- 40-60 RQD
- 60-80 RQD
- 80-100 RQD

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DRAWN	DATE	REVISED
LMC	04/15	5/11/2015 3:06 PM

\2015\REPORTS\MODELING\FIG3-6 - WHEX_RQD.DWG

RQD BLOCK MODEL PROJECTED ONTO WHEX DESIGN

AGA-CCV

SCALE 1"=500'

FIGURE 3-6

Figure 3-7
Composite and Block Model Log of Q´

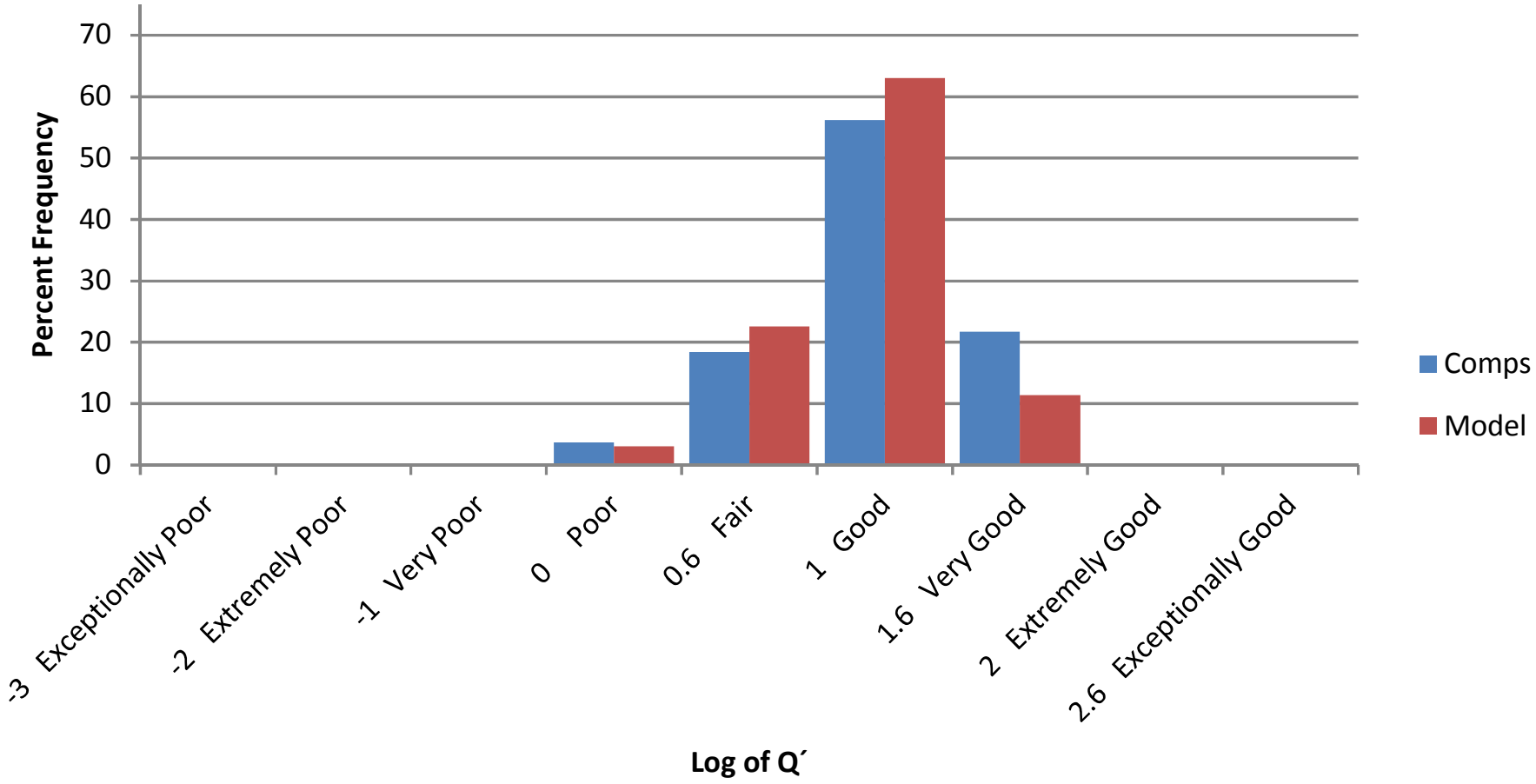
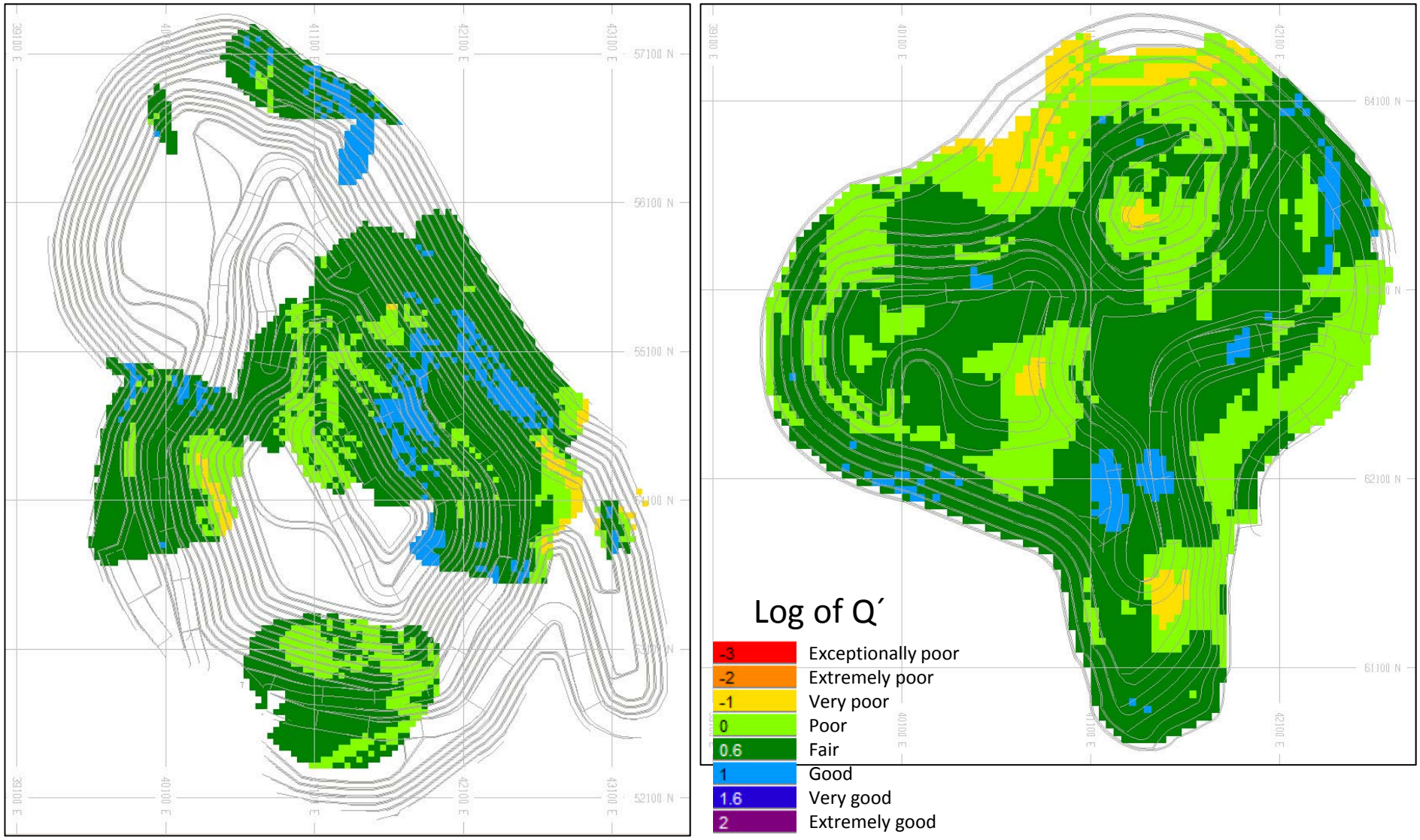


Figure 3-8
Log of Q´ on Final Pits



APPENDIX D

2015 LABORATORY TESTING

Triaxial Compression Test Results

CALL & NICHOLAS, INC.

GEOMECHANICAL LABORATORY

TUCSON, ARIZONA USA

Project #	15700	Triaxial Compression Test Results	Client	CC&V
Date	9/2/2015		Location	Cripple Creek
Technician	EK	**Failure Data:**	Sample #	**15700-GT11-4-0237**
		Sample # 15700-GT11-4-0237	Rock Type	GHP
			Density :	141.2 (pcf)
				2,261.5 (kg/m^3)

Sample Data :	
Sample # :	15700-GT11-4-0237
Rock Type:	GHP
Hole # :	GT11-4
Depth :	237.1 - 238.8
Alterations:	
Diameter :	2.400 (in)
Height :	4.891 (in)
Weight :	819.91 (gm)
Area :	4.523 (in^2)
Volume :	22.124 (in^3)

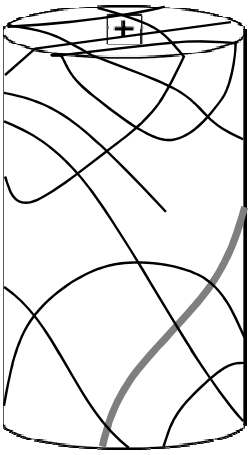
Rock Code:	

U.S. Standard		
Sigma 3 (psi)	**Sigma 1** (psi)	
1,000	18,314	**Peak**
0	0	**Residuals**
0	0	
0	0	
0	0	

Metric Standard		
Sigma 3 (MPa)	**Sigma 1** (MPa)	
6.90	126.3	**Peak**
0.00	0.0	**Residuals**
0.00	0.0	
0.00	0.0	
0.00	0.0	

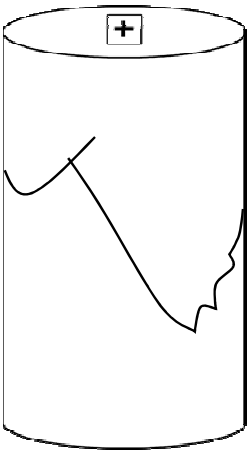
Test Data:	
Disp. Rate :	0.0003 (in/sec)
Load Rate :	(lbs/sec)
Gage Reading :	(lbs)
Mode of Failure :	Fracture
Test Duration :	(sec)

Pre-Failure Sketch | Worksheet | Post-Failure Sketch



Mode of Failure :

Fracture	XX
Intact	
Both	



NOTES:

Dia. 1	2.400	Ht. 1	4.892
Dia. 2	2.398	Ht. 2	4.896
Dia. 3	2.400	Ht. 3	4.889
Dia. 4	2.399	Ht. 4	4.888
Dia. 5	2.402	Weight (gm)	819.91
Dia. 6	2.399	Sample #	15700-GT11-4-0237

Sigma 3 (psi)	**Fail Load** gage (lbs)
1,000	82,840



15700-GT11-4-0237 Pre Test



15700-GT11-4-0237 Post Test

CALL & NICHOLAS, INC.

GEOMECHANICAL LABORATORY

TUCSON, ARIZONA USA

Project #	15700	Triaxial Compression Test Results	Client	CC&V
Date	9/2/2015		Location	Cripple Creek
Technician	EK	**Failure Data:**	Sample #	**15700-GT11-4-0290-A**
		Sample # 15700-GT11-4-0290-A	Rock Type	GHP
			Density :	153.0 (pcf)
				2,450.1 (kg/m^3)

Sample Data :	
Sample # :	15700-GT11-4-0290-A
Rock Type:	GHP
Hole # :	GT11-4
Depth :	290.2 - 291.3
Alterations:	
Diameter :	2.395 (in)
Height :	5.012 (in)
Weight :	906.84 (gm)
Area :	4.506 (in^2)
Volume :	22.586 (in^3)

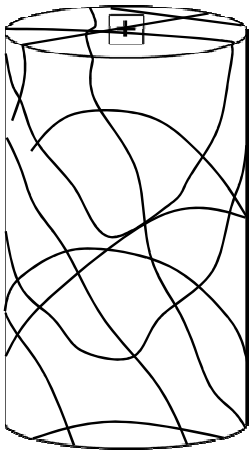
Rock Code:	

U.S. Standard		
Sigma 3 (psi)	**Sigma 1** (psi)	
500	12,427	**Peak**
0	0	**Residuals**
0	0	
0	0	
0	0	

Metric Standard		
Sigma 3 (MPa)	**Sigma 1** (MPa)	
3.45	85.7	**Peak**
0.00	0.0	**Residuals**
0.00	0.0	
0.00	0.0	
0.00	0.0	

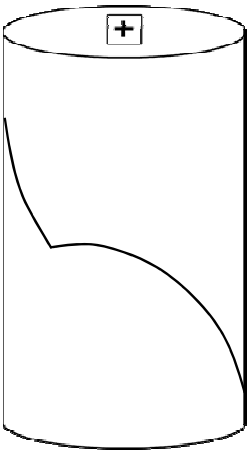
Test Data:	
Disp. Rate :	0.0003 (in/sec)
Load Rate :	(lbs/sec)
Gage Reading :	(lbs)
Mode of Failure :	Fracture
Test Duration :	(sec)

Pre-Failure Sketch | Worksheet | Post-Failure Sketch



Mode of Failure :

Fracture	XX
Intact	
Both	



NOTES:

Dia. 1	2.395	Ht. 1	5.011
Dia. 2	2.396	Ht. 2	5.014
Dia. 3	2.398	Ht. 3	5.014
Dia. 4	2.397	Ht. 4	5.010
Dia. 5	2.392	Weight (gm)	906.84
Dia. 6	2.394	Sample #	15700-GT11-4-0290-A

Sigma 3 (psi)	**Fail Load** gage (lbs)
500	56,000



15700-GT11-4-0290-A Pre Test



15700-GT11-4-0290-A Post Test

CALL & NICHOLAS, INC.

GEOMECHANICAL LABORATORY

TUCSON, ARIZONA USA

Project #	15700	Triaxial Compression Test Results	Client	CC&V
Date	9/2/2015		Location	Cripple Creek
Technician	EK	**Failure Data:**	Sample #	**15700-GT11-4-0290-B**
		Sample # 15700-GT11-4-0290-B	Rock Type	GHP
			Density :	154.0 (pcf)
				2,466.2 (kg/m^3)

Sample Data :	
Sample # :	15700-GT11-4-0290-B
Rock Type:	GHP
Hole # :	GT11-4
Depth :	290.2 - 291.3
Alterations:	
Diameter :	2.395 (in)
Height :	4.943 (in)
Weight :	899.83 (gm)
Area :	4.505 (in^2)
Volume :	22.265 (in^3)

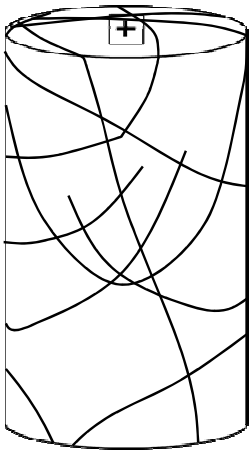
Rock Code:	

U.S. Standard		
Sigma 3 (psi)	**Sigma 1** (psi)	
1,000	17,935	**Peak**
0	0	**Residuals**
0	0	
0	0	
0	0	

Metric Standard		
Sigma 3 (MPa)	**Sigma 1** (MPa)	
6.90	123.7	**Peak**
0.00	0.0	**Residuals**
0.00	0.0	
0.00	0.0	
0.00	0.0	

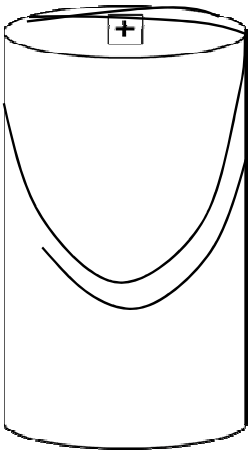
Test Data:	
Disp. Rate :	0.0003 (in/sec)
Load Rate :	(lbs/sec)
Gage Reading :	(lbs)
Mode of Failure :	Fracture
Test Duration :	(sec)

Pre-Failure Sketch | Worksheet | Post-Failure Sketch



Mode of Failure :

Fracture	XX
Intact	
Both	



NOTES:

Dia. 1	2.395	Ht. 1	4.948
Dia. 2	2.395	Ht. 2	4.942
Dia. 3	2.397	Ht. 3	4.938
Dia. 4	2.395	Ht. 4	4.943
Dia. 5	2.394	Weight (gm)	899.83
Dia. 6	2.395	Sample #	15700-GT11-4-0290-B

Sigma 3 (psi)	**Fail Load** gage (lbs)
1,000	80,790



15700-GT11-4-0290-B Pre Test



15700-GT11-4-0290-B Post Test

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Project #	15700	Triaxial Compression Test Results	Client	CC&V
Date	9/2/2015		Location	Cripple Creek
Technician	EK	**Failure Data:**	Sample #	**15700-GT11-4-0325**
		Sample # 15700-GT11-4-0325	Rock Type	GHP
			Density :	149.3 (pcf)
				2,391.6 (kg/m^3)

Sample Data :	
Sample # :	15700-GT11-4-0325
Rock Type:	GHP
Hole # :	GT11-4
Depth :	325.2 - 326.0
Alterations:	
Diameter :	2.395 (in)
Height :	4.466 (in)
Weight :	788.97 (gm)
Area :	4.507 (in^2)
Volume :	20.131 (in^3)

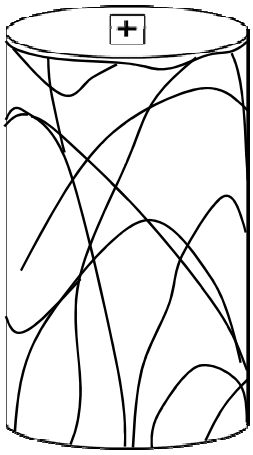
Rock Code:	

U.S. Standard		
Sigma 3 (psi)	**Sigma 1** (psi)	
1,500	17,133	**Peak**
0	0	**Residuals**
0	0	
0	0	
0	0	

Metric Standard		
Sigma 3 (MPa)	**Sigma 1** (MPa)	
10.34	118.2	**Peak**
0.00	0.0	**Residuals**
0.00	0.0	
0.00	0.0	
0.00	0.0	

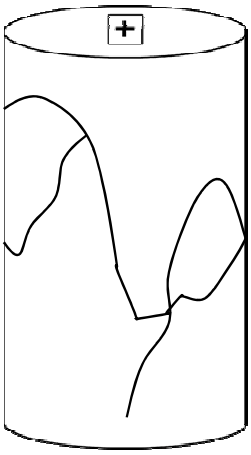
Test Data:	
Disp. Rate :	0.0003 (in/sec)
Load Rate :	(lbs/sec)
Gage Reading :	(lbs)
Mode of Failure :	Fracture
Test Duration :	(sec)

Pre-Failure Sketch | Worksheet | Post-Failure Sketch



Mode of Failure :

Fracture	XX
Intact	
Both	



NOTES: Hydrostone capped. Original Height: 4.325"

Dia. 1	2.394	Ht. 1	4.469
Dia. 2	2.395	Ht. 2	4.467
Dia. 3	2.392	Ht. 3	4.462
Dia. 4	2.396	Ht. 4	4.468
Dia. 5	2.400	Weight (gm)	788.97
Dia. 6	2.397	Sample #	15700-GT11-4-0325

Sigma 3 (psi)	**Fail Load** gage (lbs)
1,500	77,220



15700-GT11-4-0325 Pre Test



15700-GT11-4-0325 Post Test

Brazilian Disk Tension Test Results

CALL & NICHOLAS, INC.

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TUCSON, ARIZONA USA

Project #	15700	**Brazilian Disk Test Results**	Client	CC&V
Date	9/16/2015		Location	Cripple Creek
Technician	EK		Sample #	**15700-GT11-4-0237**
		Sample # **15700-GT11-4-0237**	Rock Type	GHP

T psi **1,322** psi

9.12 Mpa

Sample Data :	
Sample # :	**15700-GT11-4-0237**
Rock Type:	GHP
Hole # :	GT11-4
Depth :	237.1 - 238.8
Alterations:	
Diameter :	2.401 (in)
Length:	1.296 (in)
Density:	140.33 (pcf)

T = Indirect tensile strength

T psi	1,322 (psi)
	9.1 Mpa

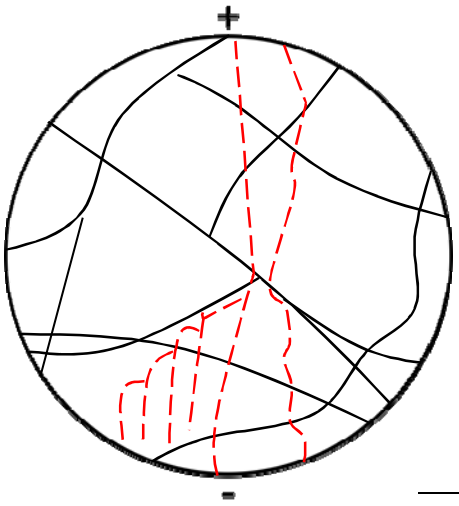
Test Data:	
Disp. Rate :	
Load Rate :	89 (lbs/sec)
Gage Reading :	6,460 (lbs)
Mode of Failure :	Both

Mode of Failure :

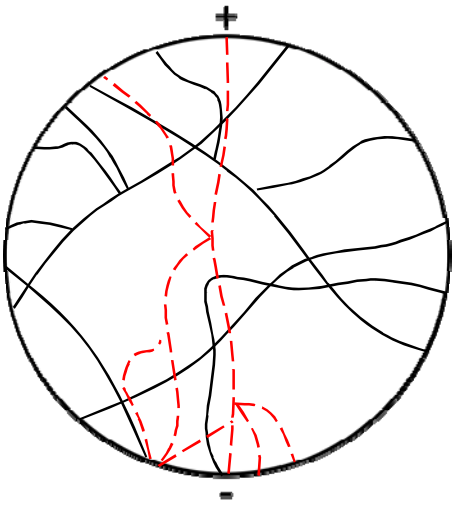
Fracture	
Intact	
Both	XX

Worksheet

Front View



Back View



——— Pre-existing Weakness Plane

- - - - - - - Post Failure Fracture

Dia. 1	2.402	Ht. 1	1.294			
Dia. 2	2.403	Ht. 2	1.298	**Fail Load**	6,460	lbs Force
Dia. 3	2.396	Ht. 3	1.299			
Dia. 4	2.400	Ht. 4	1.295			
Dia. 5	2.405	Weight	216.160			
Dia. 6	2.401	Sample #	**15700-GT11-4-0237**			

NOTES:

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Project #	15700	**Brazilian Disk Test Results**	Client	CC&V
Date	9/15/2015		Location	Cripple Creek
Technician	EK		Sample #	**15700-GT11-4-0290**
		Sample # **15700-GT11-4-0290**	Rock Type	GHP

T psi _____ psi

_____ Mpa

Sample Data :	
Sample # :	**15700-GT11-4-0290**
Rock Type:	GHP
Hole # :	GT11-4
Depth :	290.2 - 291.3
Alterations:	
Diameter :	2.407 (in)
Length:	1.225 (in)
Density:	152.11 (pcf)

T = Indirect tensile strength

T psi	(psi)
	Mpa

Test Data:		
Disp. Rate :		
Load Rate :	84	(lbs/sec)
Gage Reading :	NO TEST	(lbs)
Mode of Failure :	Fracture	

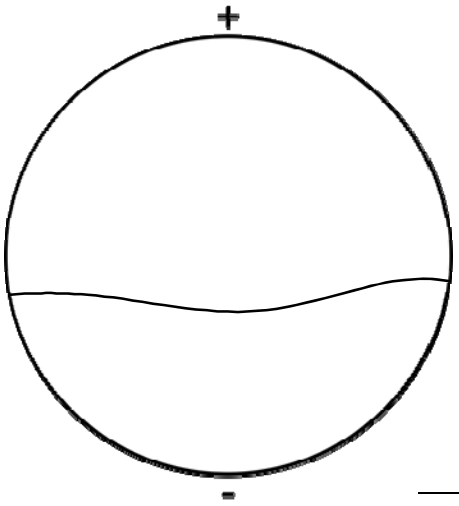
Mode of Failure :

Fracture	XX
Intact	
tl	

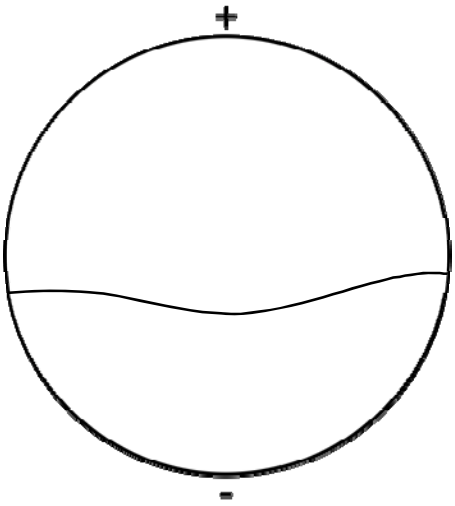
NO TEST

Worksheet

Front View



Back View



——— Pre-existing Weakness Plane

- - - - - - - Post Failure Fracture

Dia. 1	2.420	Ht. 1	1.226
Dia. 2	2.404	Ht. 2	1.224
Dia. 3	2.404	Ht. 3	1.228
Dia. 4	2.402	Ht. 4	1.225
Dia. 5	2.406	Weight	222.570
Dia. 6	2.406	Sample #	**15700-GT11-4-0290**

Fail Load NO TEST lbs Force

NOTES: Sample fractured pre-test

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GEOMECHANICAL LABORATORY

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Project #	15700	**Brazilian Disk Test Results**	Client	CC&V
Date	9/16/2015		Location	Cripple Creek
Technician	EK		Sample #	**15700-GT11-4-0325**
		Sample # **15700-GT11-4-0325**	Rock Type	GHP

T psi **1,019** psi

7.03 Mpa

Sample Data :	
Sample # :	**15700-GT11-4-0325**
Rock Type:	GHP
Hole # :	GT11-4
Depth :	325.2 - 326.0
Alterations:	
Diameter :	2.413 (in)
Length:	0.824 (in)
Density:	148.22 (pcf)

T = Indirect tensile strength

T psi	1,019 (psi)
	7.0 Mpa

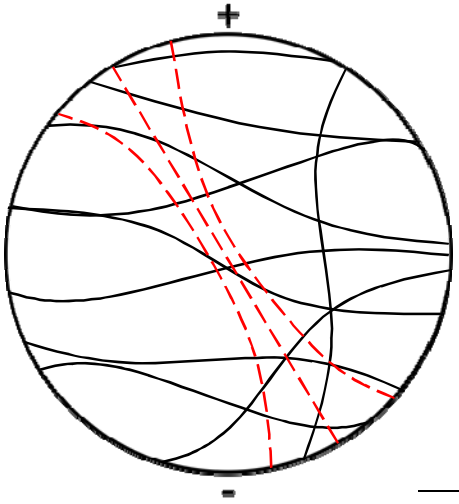
Test Data:	
Disp. Rate :	
Load Rate :	57 (lbs/sec)
Gage Reading :	3,180 (lbs)
Mode of Failure :	Fracture

Mode of Failure :

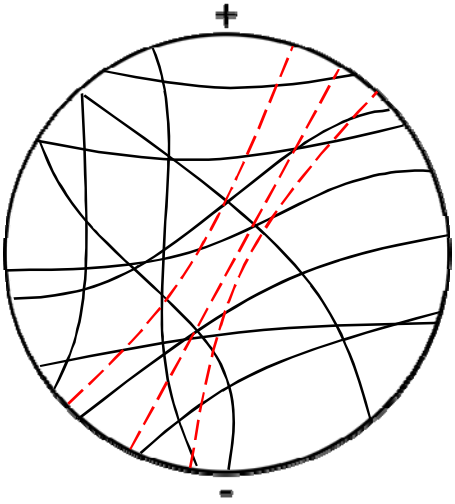
Fracture	XX
Intact	
Both	

Worksheet

Front View



Back View



——— Pre-existing Weakness Plane

- - - - - - - Post Failure Fracture

Dia. 1	2.418	Ht. 1	0.820			
Dia. 2	2.418	Ht. 2	0.826	**Fail Load**	3,180	lbs Force
Dia. 3	2.415	Ht. 3	0.827			
Dia. 4	2.407	Ht. 4	0.823			
Dia. 5	2.410	Weight	146.590			
Dia. 6	2.410	Sample #	**15700-GT11-4-0325**			

NOTES:

Wet Sieve and Atterberg Limits Test Results

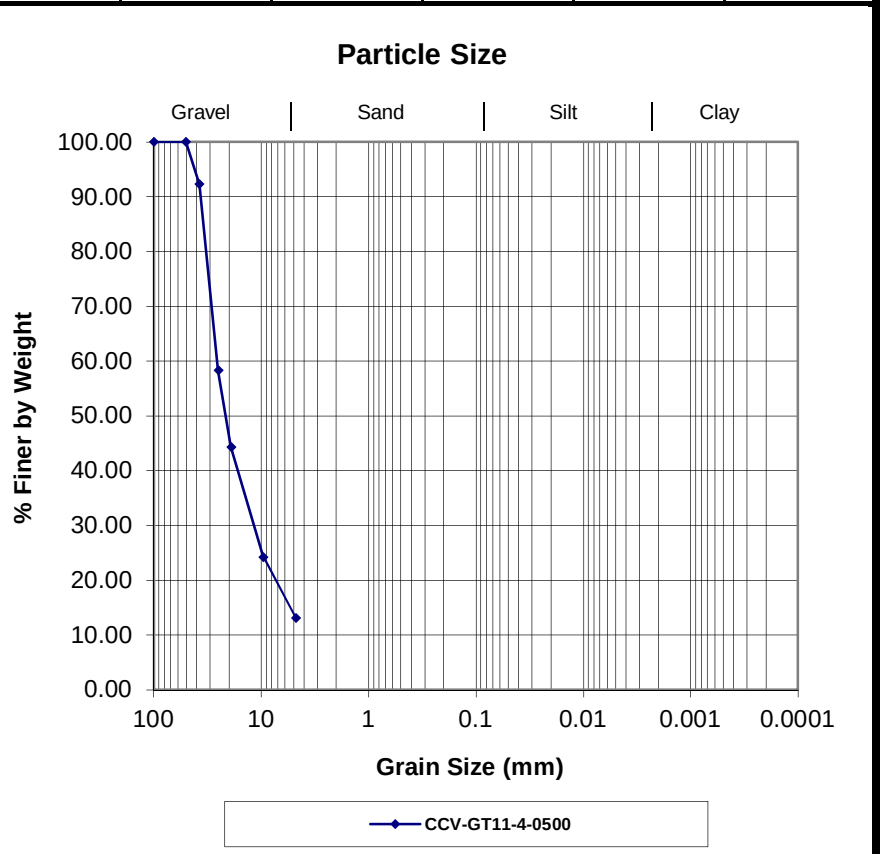
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Sieve Analysis & Soil Classification

Sieve Size U.S.	mm	Retained Weight Grams	Retained % of Weight	Cumulative % Retained Coarser	Cumulative % Passing Finer
4"	100	0.00	0.00	0.00	100.00
2"	50.0	0.00	0.00	0.00	100.00
1.5"	37.5	341.22	7.70	7.70	92.30
1"	25.0	1509.00	34.03	41.73	58.27
3/4"	19.0	617.96	13.94	55.66	44.34
3/8"	9.5	894.16	20.16	75.83	24.17
# 4	4.75	488.10	11.01	86.83	13.17
# 10	2.00	-	-	-	-
# 20	0.850	-	-	-	-
# 40	0.425	-	-	-	-
# 60	0.250	-	-	-	-
# 120	0.125	-	-	-	-
# 200	0.075	-	-	-	-
Pan		-	-	-	-
Total		4434.24			

Coarse Gravel %	Fine Gravel %	Coarse Sand %	Medium Sand %	Fine Sand %	Silt / Clay %
55.66	31.17	13.17	-	-	-

Dia (mm)	Hydrometer Data		% Passing
-			-
-	Working Values & Coefficients		-
-	D_{10}	3.7	-
-	D_{30}	11.57	-
-	D_{60}	25.65	-
-	**Cu**	6.9	-
-	**Cc**	1.4	-
-	**Starting Wt.**	4434.24	-
-			-
-	**Field USCS**	GHP	-
-	ASTM D 422 Method		-



Project #	**15700**
Hole #	GT11-4
Depth	500.5 - 504.7
Client	CC&V
Location	Cripple Creek
Date	8/18/2015
Technician	CMG

Notes: **Less than 12% passes a No. 200; Hydrometer not tested. Not enough material for Atterbergs. Fines are Non-Plastic**

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As Received Moisture %		1.10%	
LL	N/A	PL	NP
PI	NP	Flow Index	N/A
USCS	**GW**	Silt/Clay %	-
Description	Well-graded gravel		
Sample #	**CCV-GT11-4-0500**		



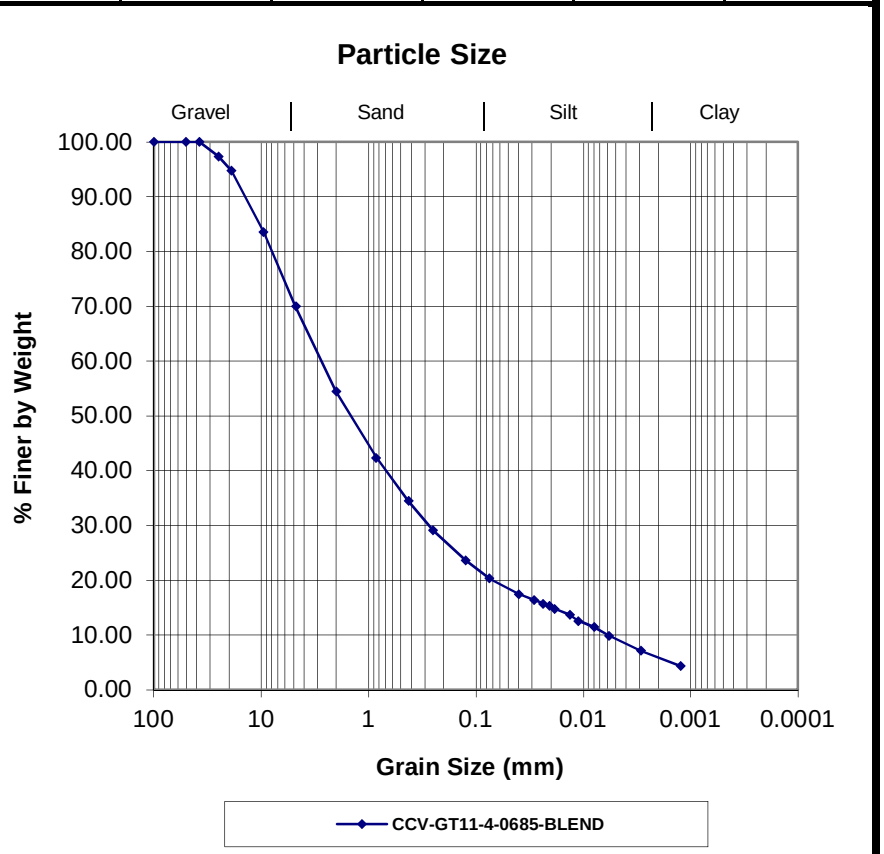
As Received		
Project #	15700	
Coordinates	GT11-4	
Depth	500.5 - 504.7	
USCS	**GW**	Well-graded gravel

Sieve Analysis & Soil Classification

Sieve Size U.S.	mm	Retained Weight Grams	Retained % of Weight	Cumulative % Retained Coarser	Cumulative % Passing Finer
4"	100	0.00	0.00	0.00	100.00
2"	50.0	0.00	0.00	0.00	100.00
1.5"	37.5	0.00	0.00	0.00	100.00
1"	25.0	32.29	2.62	2.62	97.38
3/4"	19.0	31.43	2.55	5.18	94.82
3/8"	9.5	139.06	11.30	16.48	83.52
# 4	4.75	167.00	13.57	30.05	69.95
# 10	2.00	190.20	15.45	45.50	54.50
# 20	0.850	149.46	12.14	57.65	42.35
# 40	0.425	97.15	7.89	65.54	34.46
# 60	0.250	65.69	5.34	70.88	29.12
# 120	0.125	67.32	5.47	76.35	23.65
# 200	0.075	40.90	3.32	79.67	20.33
Pan		250.18	20.33	100	0
Total		1230.68			

Dia (mm)	Hydrometer Data		% Passing
0.04500			17.89
0.03375	**Working Values & Coefficients**		16.88
0.02500	D_{10}	0.006	15.90
0.01875	D_{30}	0.2788	14.85
0.01400	D_{60}	2.979	13.79
0.01000	**Cu**	493.2	12.18
0.00750	**Cc**	4.3	11.15
0.00500	**Starting Wt.**	1230.68	9.18
0.00375			7.97
0.00250	**Field USCS**	GHP	6.47
0.00150	ASTM D 422 Method		4.80

Coarse Gravel %	Fine Gravel %	Coarse Sand %	Medium Sand %	Fine Sand %	Silt / Clay %
5.18	**24.87**	**15.45**	**20.04**	**14.13**	**20.33**



Project #	**15700**
Hole #	GT11-4
Depth	685-685.4/686.2-687.9
Client	CC&V
Location	Cripple Creek
Date	8/26/2015
Technician	JM

Notes: **Fines classify as CL-ML**

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As Received Moisture %		1.12%	
LL	22	PL	15
PI	7	Flow Index	N/A
USCS	**SC-SM**	Silt/Clay %	20.33
Description	Silty, clayey sand with gravel		
Sample #	**CCV-GT11-4-0685-BLEND**		

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Project #	15700	**ATTERBERG LIMITS BY CASAGRANDE ASTM D4318**		Date	9/16/2015
Hole #	GT11-4			Tech	
Depth	685-685.4/686.2-687.9	**CCV-GT11-4-0685-BLEND**		Client	CC&V
Estimated USCS	GHP			Location	Cripple Creek

Liquid Limit determination by Casagrande Method (Method A)

Can #		9	29				
Weight of can (g)		30.964	31.156				
WET Sample & Can(g)		42.982	43.620				
DRY wt 1	17-Sep	40.831	41.385				
DRY wt 2		40.817	41.364				
DRY wt 3	18-Sep	40.820	41.373				
Weight of Moisture(g)		2.165	2.256				
Weight of Dry Sample		9.853	10.208				
Moisture Content %		**22.0%**	**22.1%**				
No. of Blows		**21**	**23**				

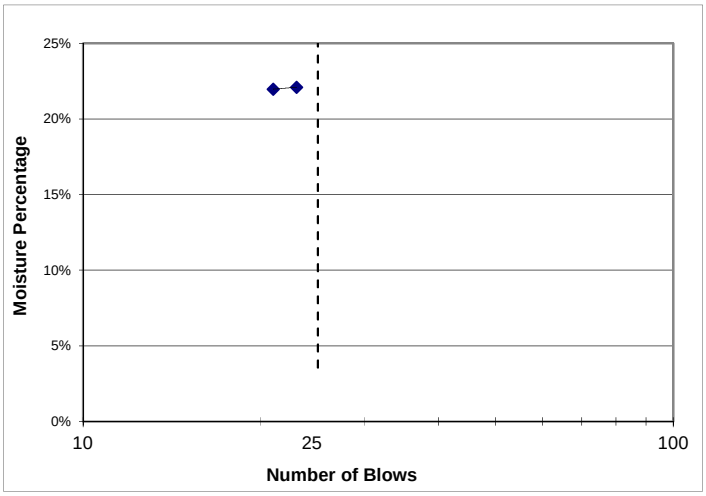
Plastic limit determination

Can #		236	318	303	423	**Average**
Weight of can (g)		11.212	11.244	11.248	11.402	
WET Sample & Can(g)		13.410	13.186	14.042	13.000	
DRY wt 1	17-Sep	13.118	12.939	13.677	12.788	
DRY wt 2	17-Sep	13.108	12.932	13.672	12.785	
DRY wt 3	18-Sep	13.112	12.934	13.676	12.786	
Weight of Moisture(g)		0.302	0.254	0.370	0.215	1.141
Weight of Dry Sample		1.896	1.688	2.424	1.383	7.391
Moisture Content %		**15.9%**	**15.0%**	**15.3%**	**15.5%**	**15.4%**

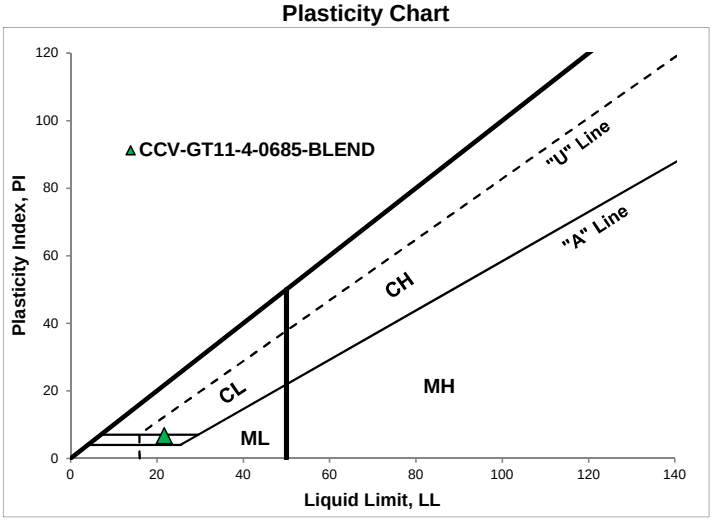
Liquid Limit determination by Single Point (Method B)

	Point 1	Point 2	Average	**Liquid Lim.**	Difference
Moisture Content %	21.973%	22.100%		**22**	0.36%
No. of Blows	21	23			
Calculated Liquid Limit	21.5%	21.9%	21.7%		

Number of Blows vs Moisture Content



Plasticity Chart



Flow Index	Liquid Limit	Plastic Limit	Plasticity Index:
N/A	22	15	7

Per ASTM 2487, Fines Classified as: **CL-ML**

Sample #	CCV-GT11-4-0685-BLEND





As Received	
Project #	15700
Coordinates	GT11-4

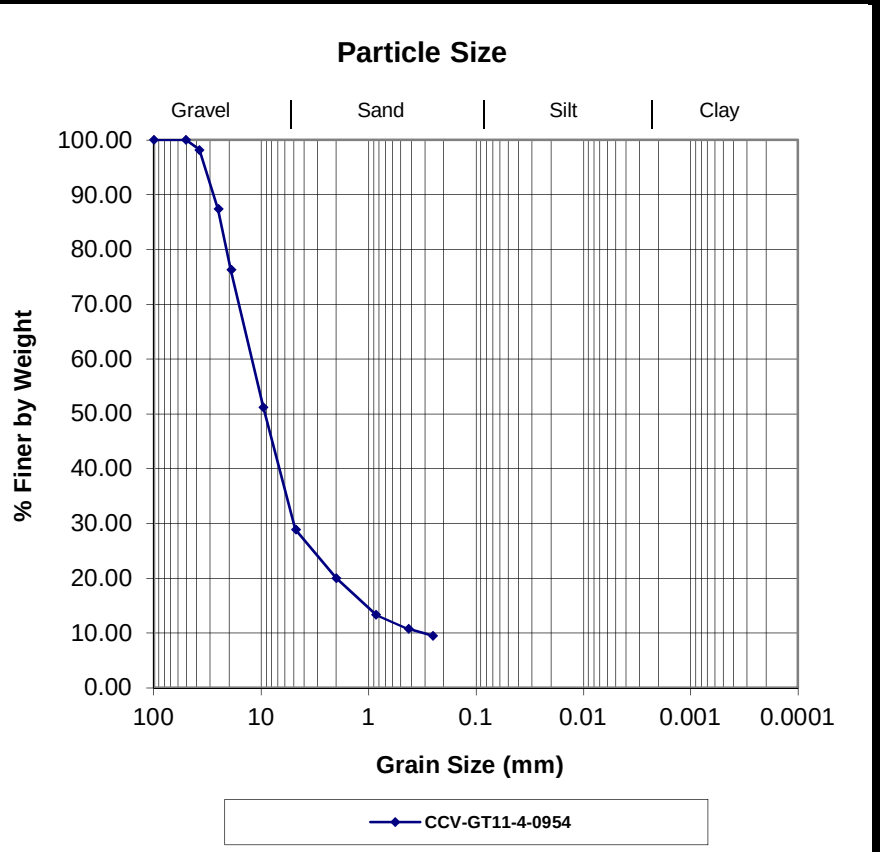
Depth	685-685.4/686.2-687.9	
USCS	**SC-SM**	Silty, clayey sand with gravel

Sieve Analysis & Soil Classification

Sieve Size U.S.	mm	Retained Weight Grams	Retained % of Weight	Cumulative % Retained Coarser	Cumulative % Passing Finer
4"	100	0.00	0.00	0.00	100.00
2"	50.0	0.00	0.00	0.00	100.00
1.5"	37.5	72.99	1.80	1.80	98.20
1"	25.0	438.99	10.82	12.62	87.38
3/4"	19.0	451.48	11.13	23.74	76.26
3/8"	9.5	1017.02	25.06	48.80	51.20
# 4	4.75	905.70	22.32	71.12	28.88
# 10	2.00	358.93	8.84	79.96	20.04
# 20	0.850	273.57	6.74	86.71	13.29
# 40	0.425	103.71	2.56	89.26	10.74
# 60	0.250	49.09	1.21	90.47	9.53
# 120	0.125	-	-	-	-
# 200	0.075	-	-	-	-
Pan		-	-	-	-
Total		4058.19			

Coarse Gravel %	Fine Gravel %	Coarse Sand %	Medium Sand %	Fine Sand %	Silt / Clay %
23.74	47.38	8.84	9.30	10.74	-

Dia (mm)	Hydrometer Data		% Passing
-			-
-	Working Values & Coefficients		-
-	D_{10}	0.272	-
-	D_{30}	4.95	-
-	D_{60}	12.16	-
-	**Cu**	44.7	-
-	**Cc**	7.4	-
-	**Starting Wt.**	4058.19	-
-			-
-	**Field USCS**	GHP	-
-	ASTM D 422 Method		-



Project #	**15700**
Hole #	GT11-4
Depth	954.8 - 958.9
Client	CC&V
Location	Cripple Creek
Date	8/18/2015
Technician	CMG

Notes: **Less than 12% passes a No. 200; Hydrometer not tested. Not enough material for Atterbergs. Fines are Non-Plastic**

CALL & NICHOLAS, INC.
GEOMECHANICAL LABORATORY
TUCSON, ARIZONA USA

As Received Moisture %		1.30%	
LL	N/A	PL	NP
PI	N/A	Flow Index	N/A
USCS	**GP**	Silt/Clay %	-
Description	Poorly graded gravel with sand		
Sample #	**CCV-GT11-4-0954**		



As Received		
Project #	15700	
Coordinates	GT11-4	
Depth	954.8 - 958.9	
USCS	**GP**	Poorly graded gravel with sand

Small-Scale Direct-Shear Test Results

CALL & NICHOLAS, INC.

Call & Nicholas, Inc.

Geomechanical Laboratory

Tucson, Arizona USA

Date	09/14/15	Area & Load Data for SSDS	*Project #*	15700
Technician	JY		*Client*	CC&V

Sample Data		
Peak/Residual	Residual	
Location	Cripple Creek	
Sample #	15700-CCV-GT11-4-0685-Blend	
Rock Type	GHP	
Drill Hole	GT11-4	
Depth	685.0 - 687.9	
Test Data		
Shear Plane	Remold	
Surface Prep	Submerged	
Shape	Circle	
Test Speed	0.00125	*in/min*
Area	4.87	*in²*
Diameter	2.490	*in*
Radius	1.245	*in*
Tilt Correction		*deg*
Plane Filling		

Adjusted Trace Data				
Normal Load (lbs)	*Shear Load (lbs)*	*Shear Area (in^2)*	*Normal Stress (psi)*	*Shear Stress (psi)*
95.7	66.5	4.1	23.3	16.2
197.7	140.5	4.1	48.2	34.2
391.7	258.7	4.1	95.4	63.0
777.3	508.1	3.9	199.6	130.5

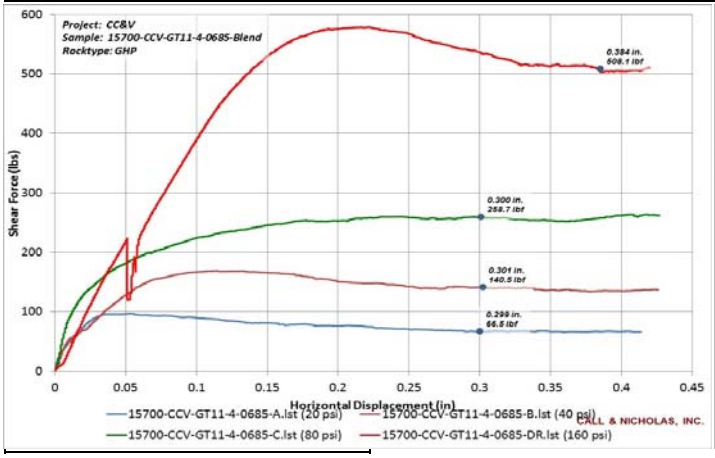
Pre Test Moisture	9.06	%
Post Test Moisture	10.07	%
Initial Density, wet	139.10	*pcf*

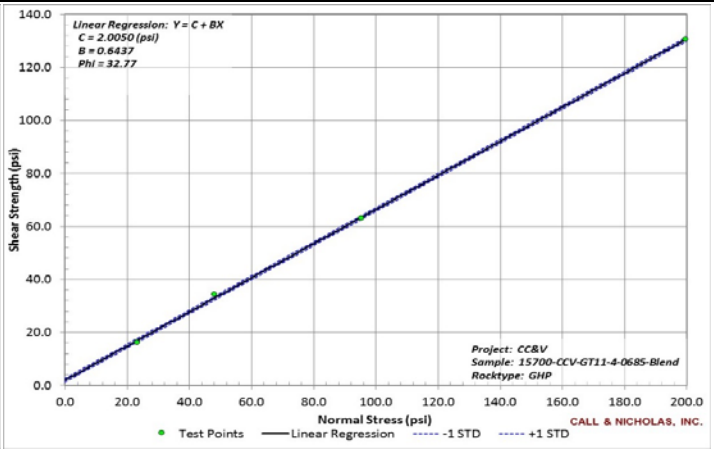
Results		
Linear: Y = BX + C		
Friction Angle	32.77	*deg*
Cohesion	2.01	*psi*

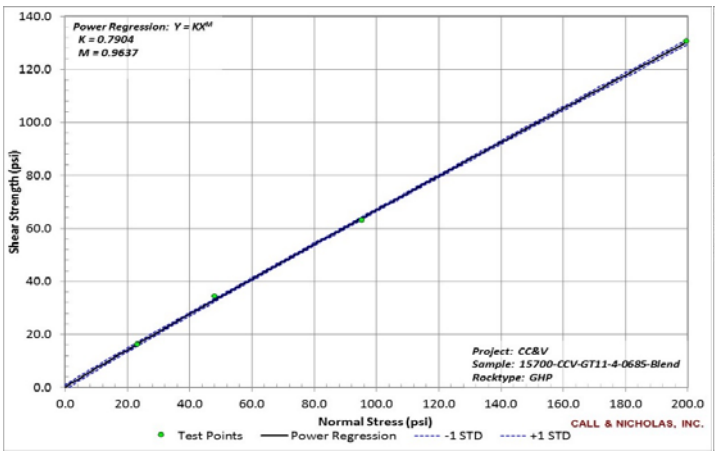
Power: Y = KX^M		
K	0.7904	*(for X in psi)*
M	0.9637	

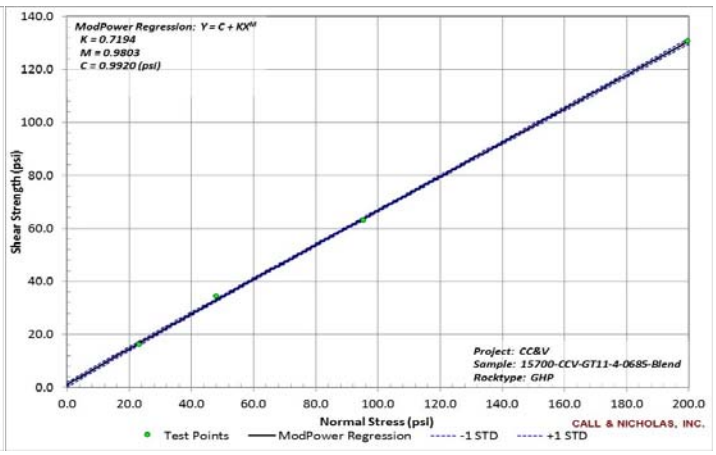
Modified Power: Y = KX^M + C		
K	0.7194	*(for X in psi)*
M	0.9803	
C	0.9920	*psi*

Plot of Raw Trace Data









Color	**Consistency**	**Plasticity**
Tan/Brown	Sandy Clay	Low Plasticity Low/Med Cementation

Notes :

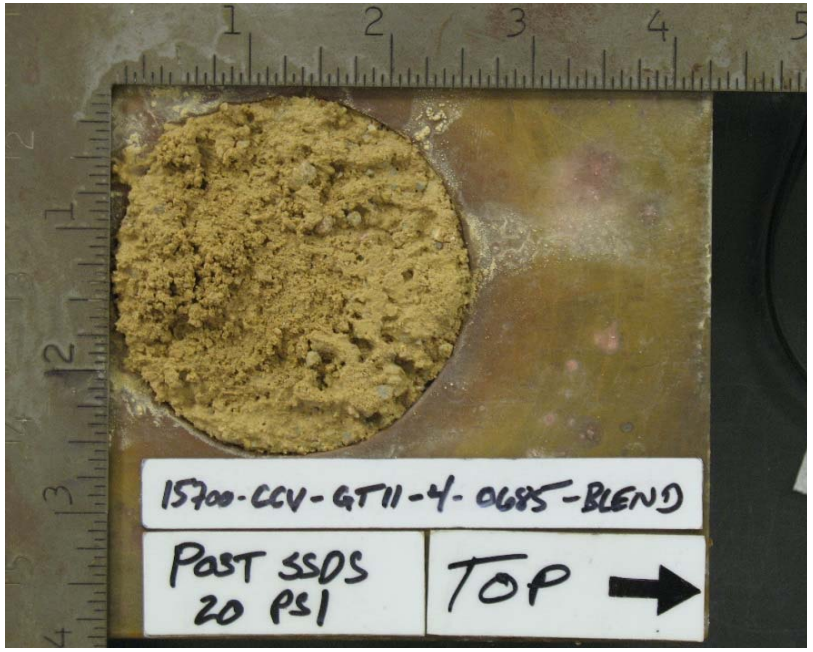
Sample is a blend of 685-685.4 & 686.2-687.9. Plastic Limit. LL=22; PL=15; PI=7. Fines classify as CL-ML. Packed to the maximum density allowed (126.9 pcf dry). Consolidated at each normal. As-rcvd moisture of 1.12%.

Sample: 15700-CCV-GT11-4-0685-Blend

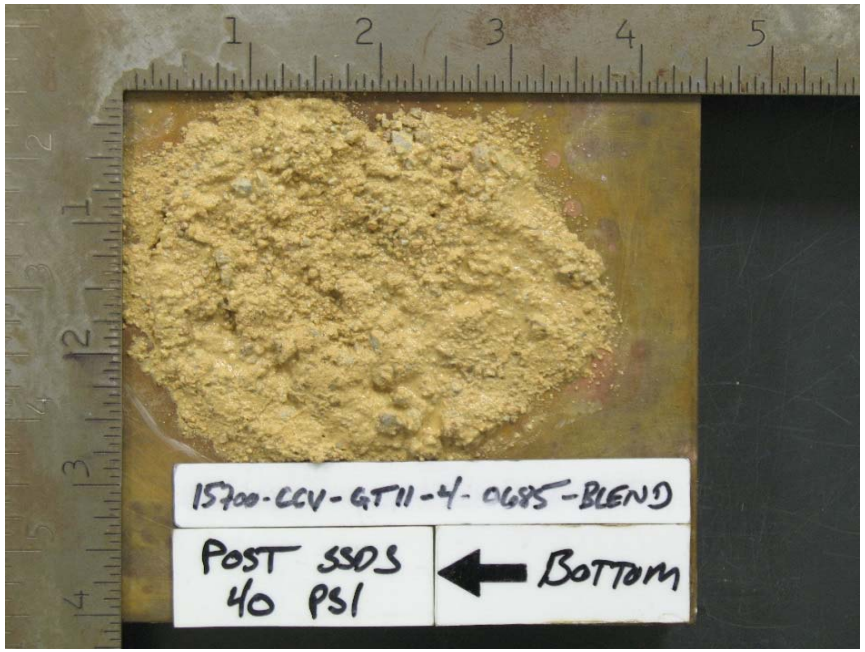
CALL & NICHOLAS, INC.



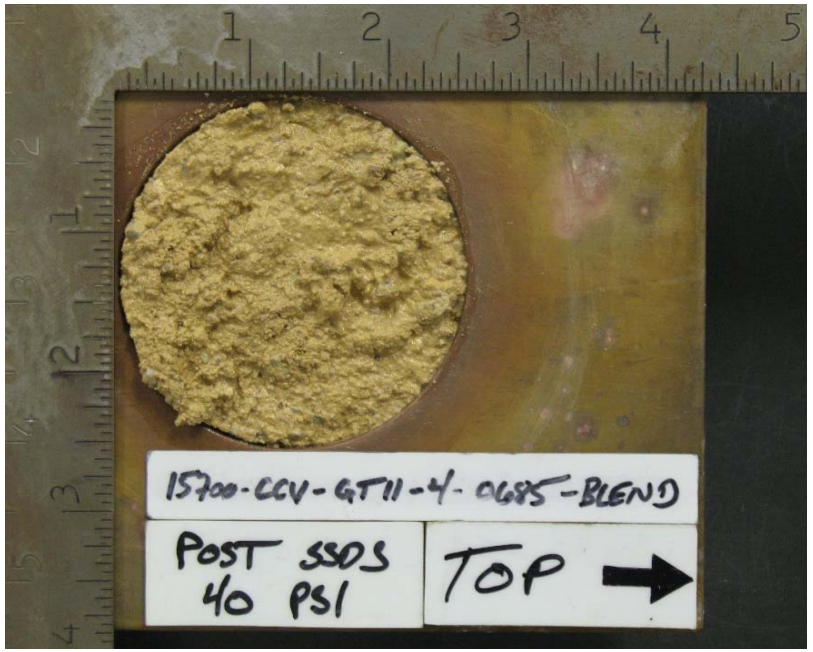
15700-CCV-GT11-4-0685-Blend - 20 psi Post Test - Bottom



15700-CCV-GT11-4-0685-Blend - 20 psi Post Test - Top



15700-CCV-GT11-4-0685-Blend - 40 psi Post Test - Bottom



15700-CCV-GT11-4-0685-Blend - 40 psi Post Test - Top

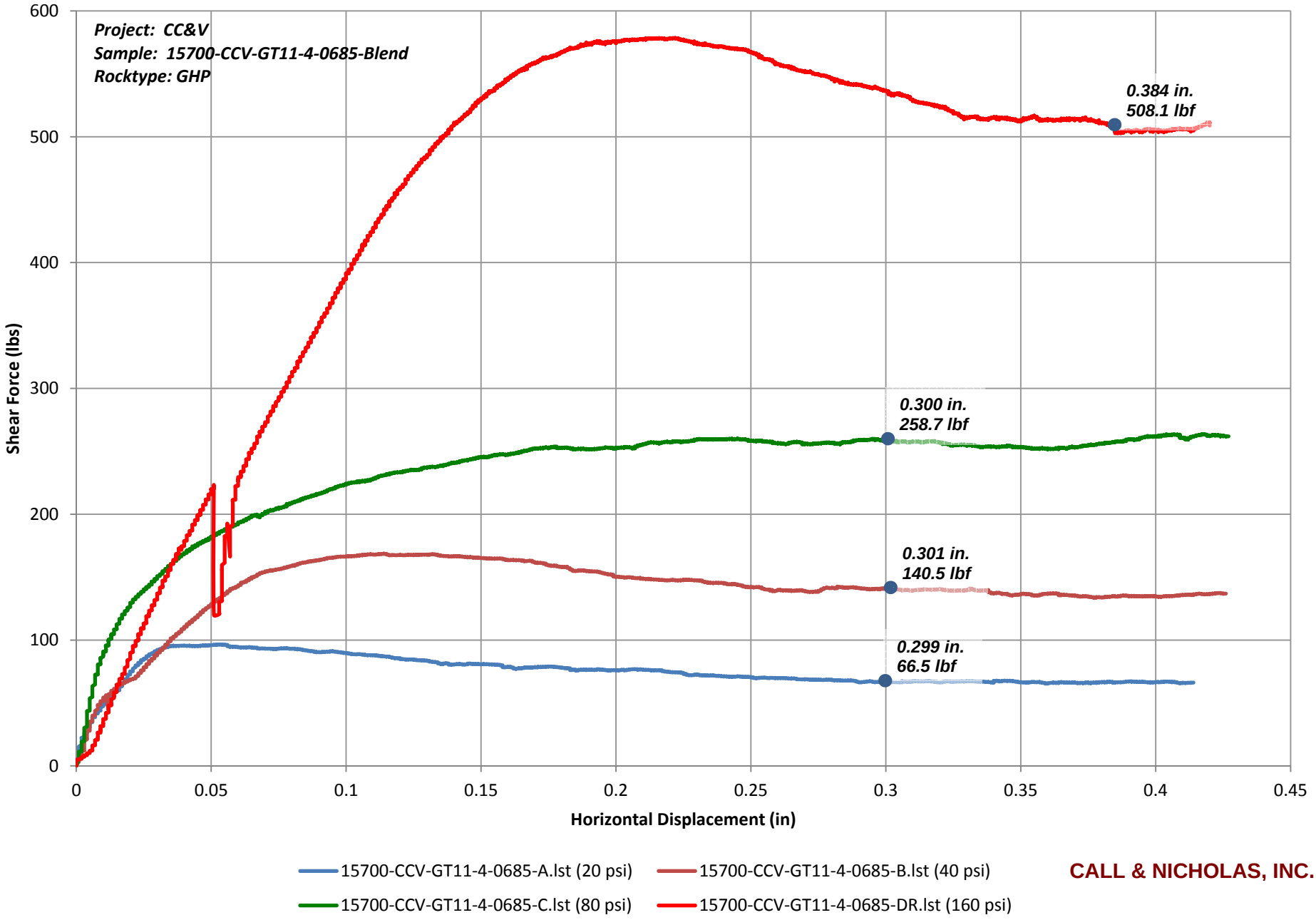


Figure 1: Direct Shear Traces

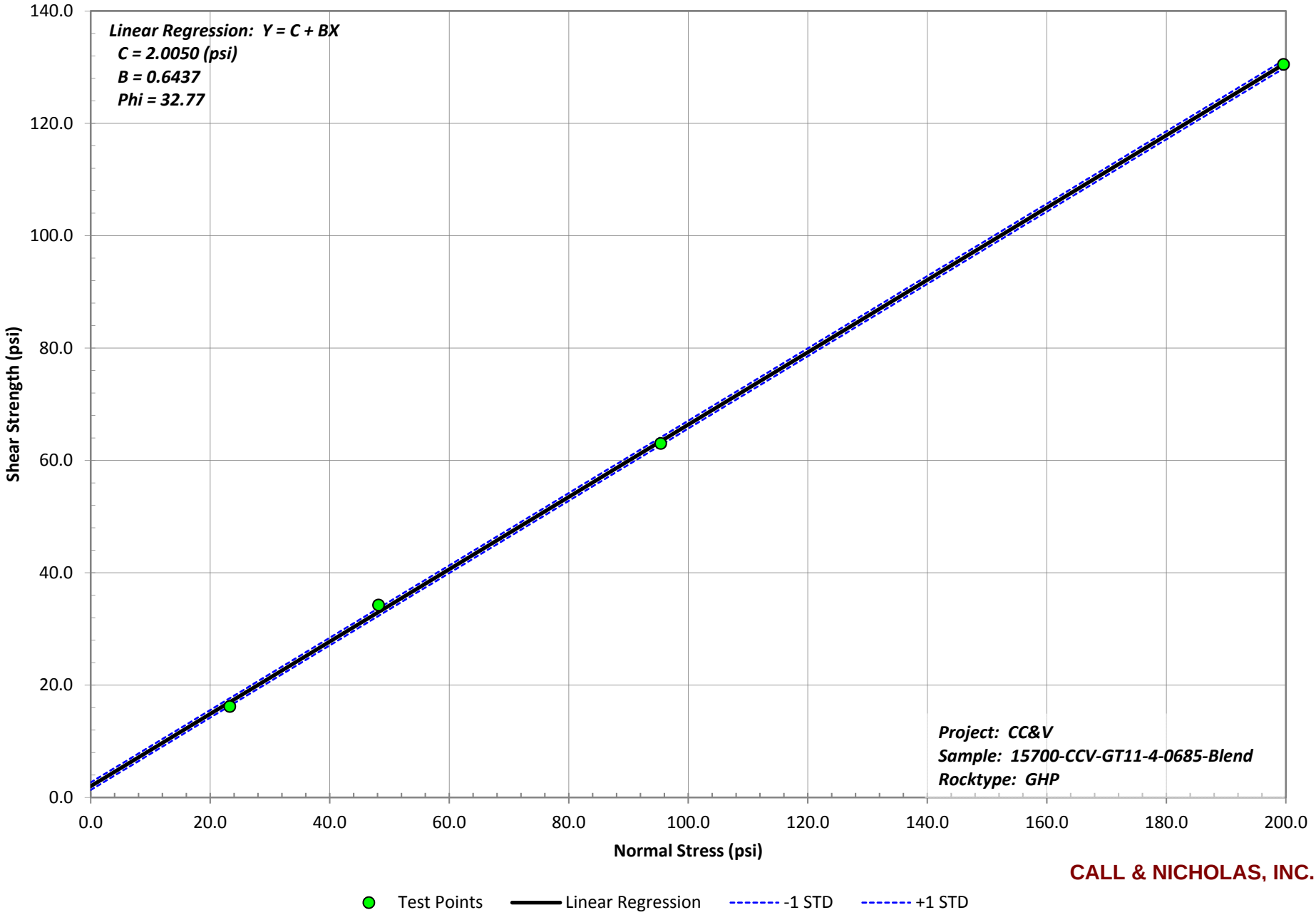
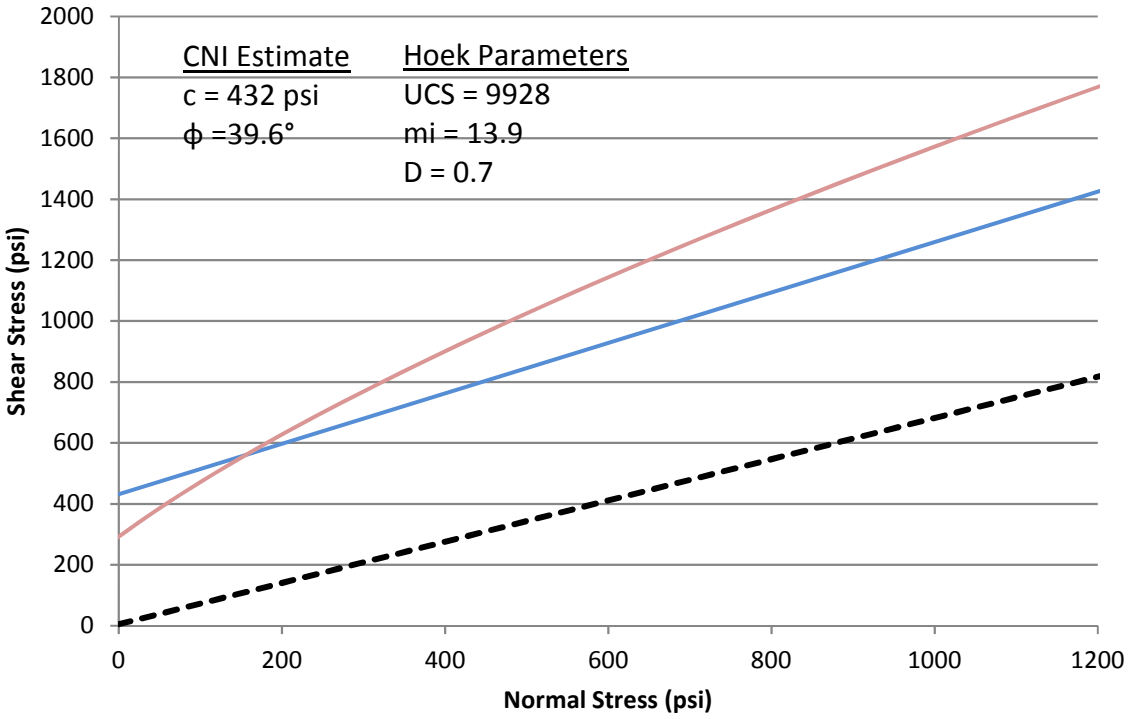


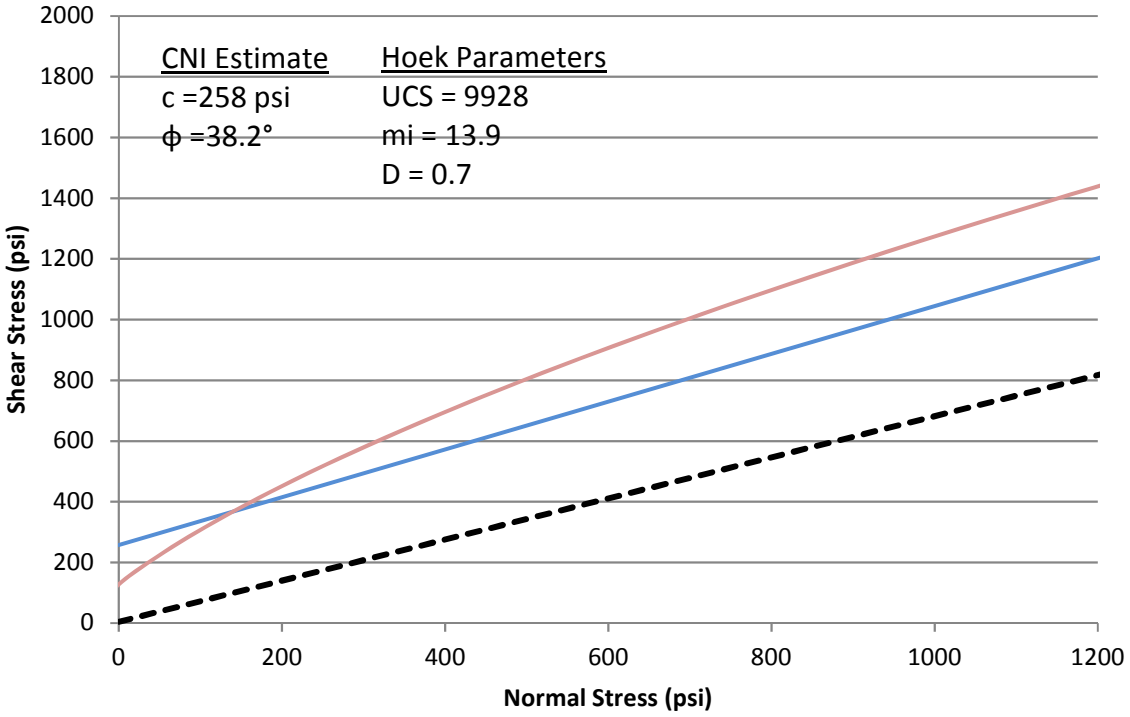
Figure 1: Linear Failure Envelope

APPENDIX E

ROCK MASS STRENGTHS

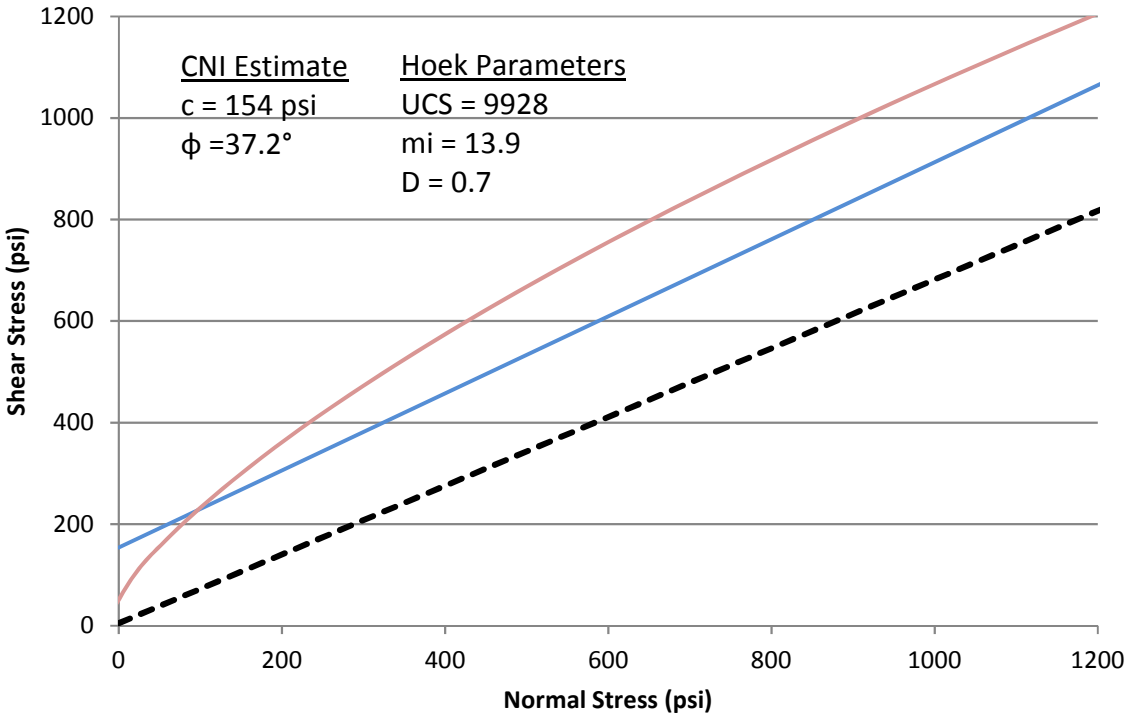


Rock-mass Strength Estimation, Cripple Creek Breccia (TBX), 90% RQD

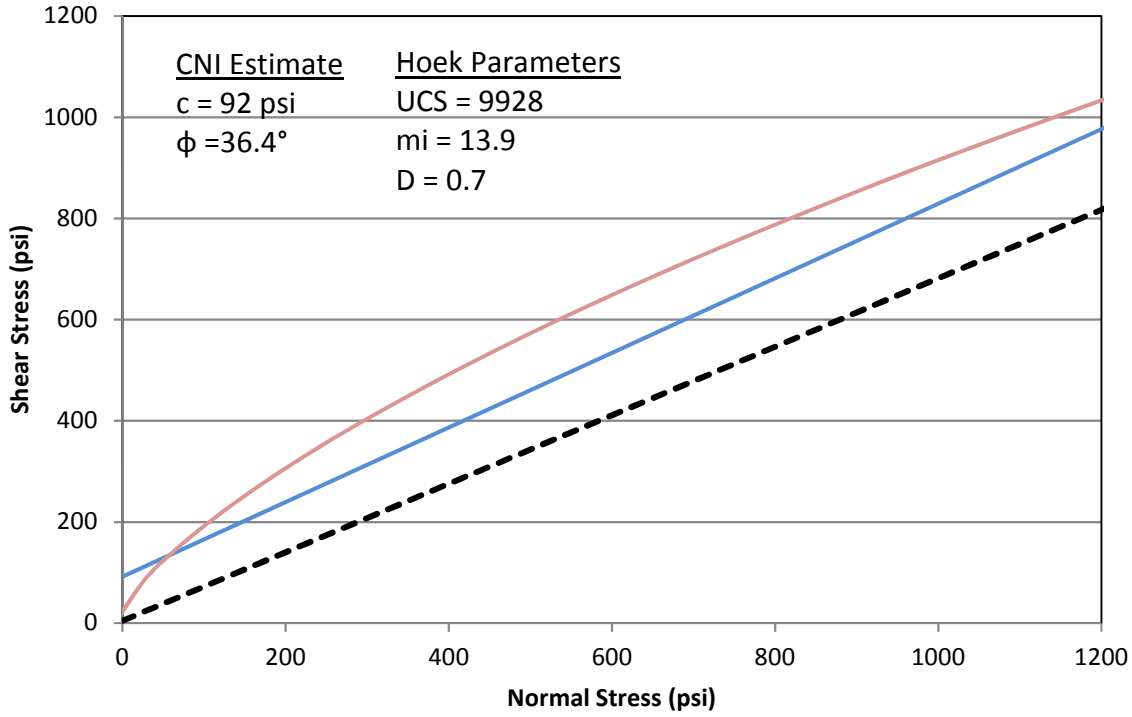


Rock-mass Strength Estimation, Cripple Creek Breccia (TBX), 70% RQD

CNI Method Rmass Estimate
Hoek-Brown Rmass Estimate (D=0.7)
Fracture Shear Strength

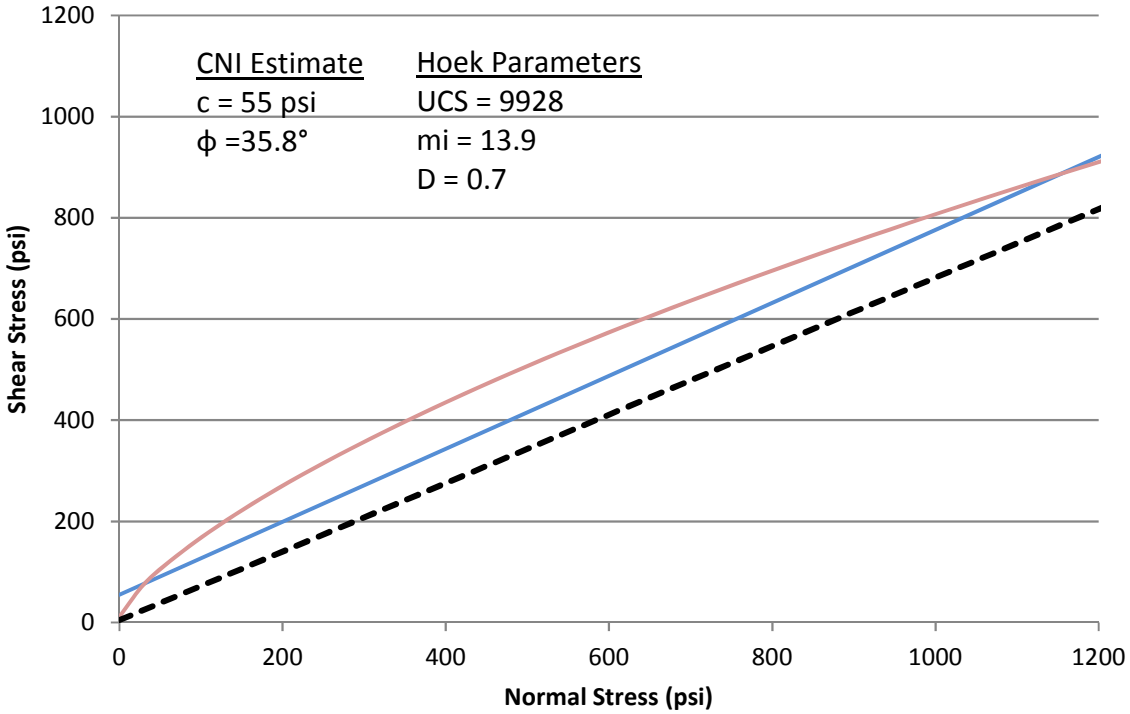


Rock-mass Strength Estimation, Cripple Creek Breccia (TBX), 50% RQD



Rock-mass Strength Estimation, Cripple Creek Breccia (TBX), 30% RQD

CNI Method Rmass Estimate
Hoek-Brown Rmass Estimate (D=0.7)
Fracture Shear Strength

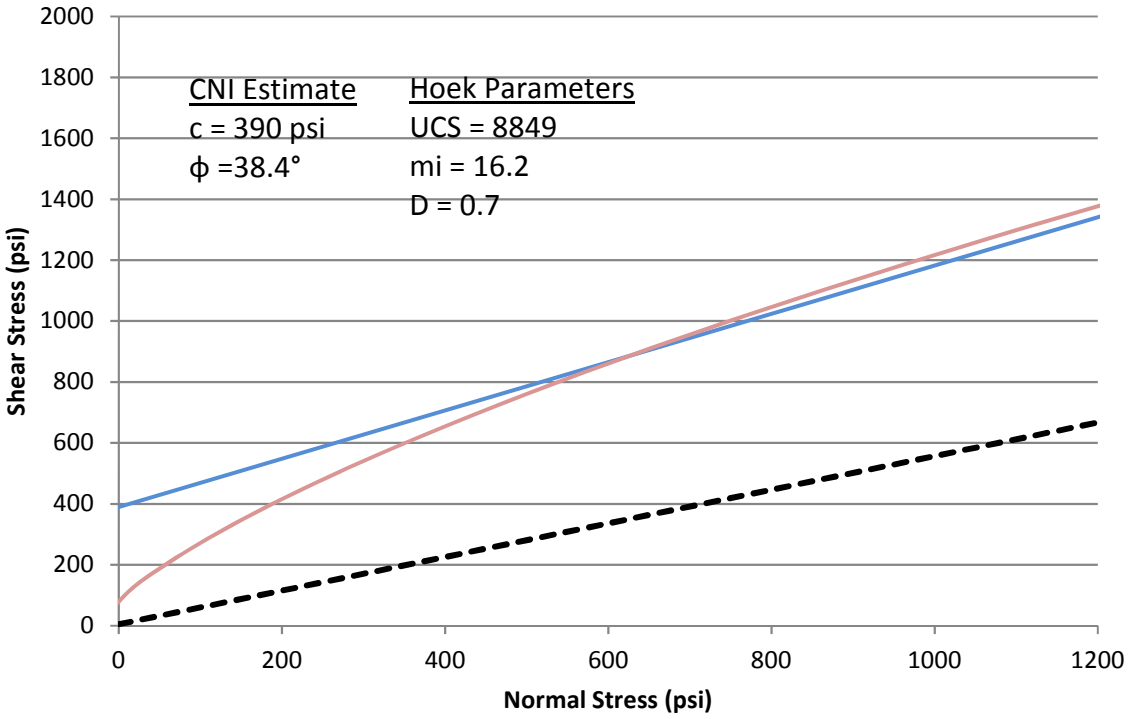


Rock-mass Strength Estimation, Cripple Creek Breccia (TBX), 10% RQD

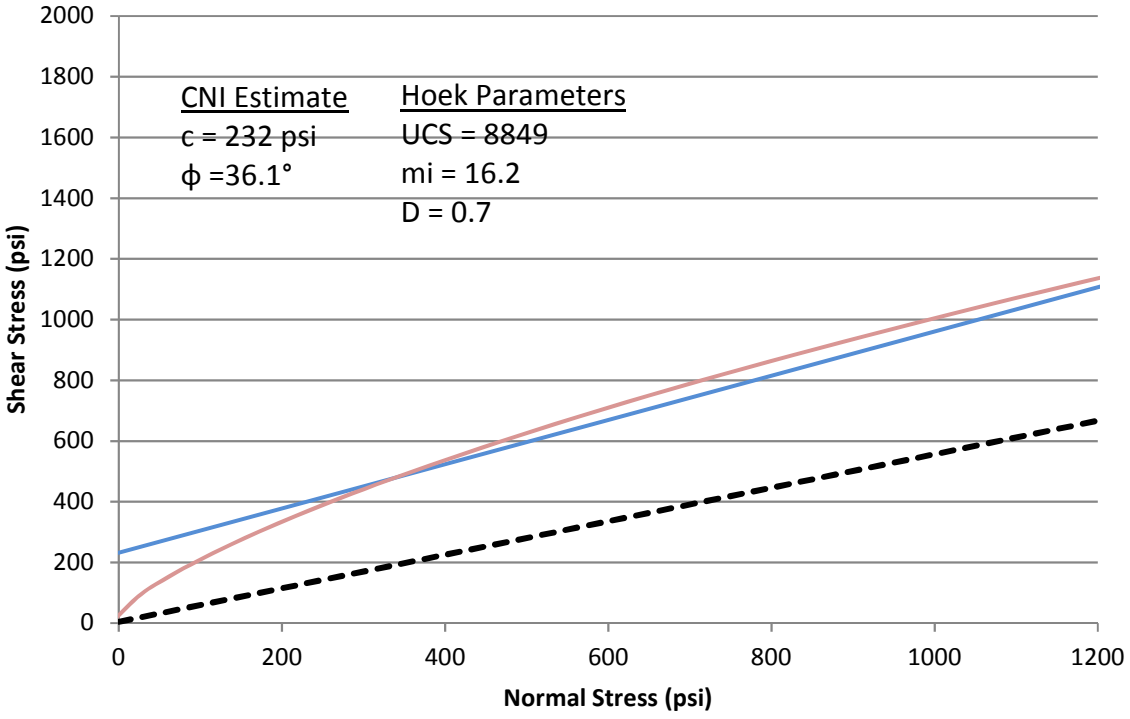
CNI Method Rmass Estimate

Hoek-Brown Rmass Estimate (D=0.7)

Fracture Shear Strength

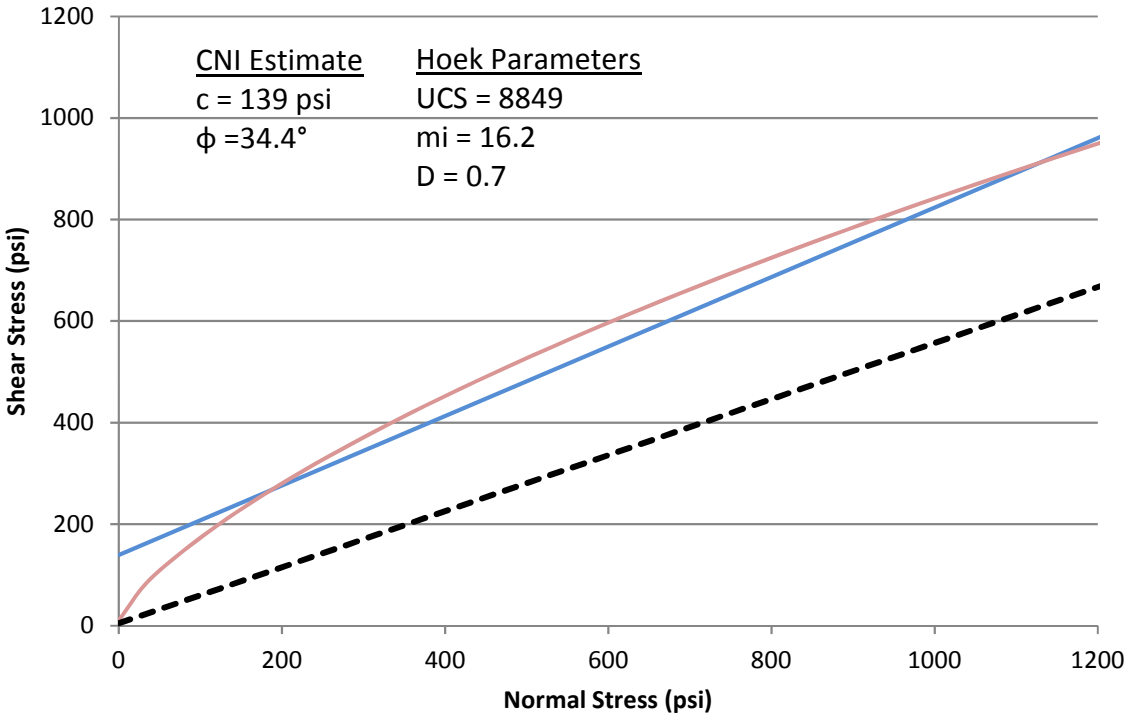


Rock-mass Strength Estimation, Phonolite (TPH), 90% RQD

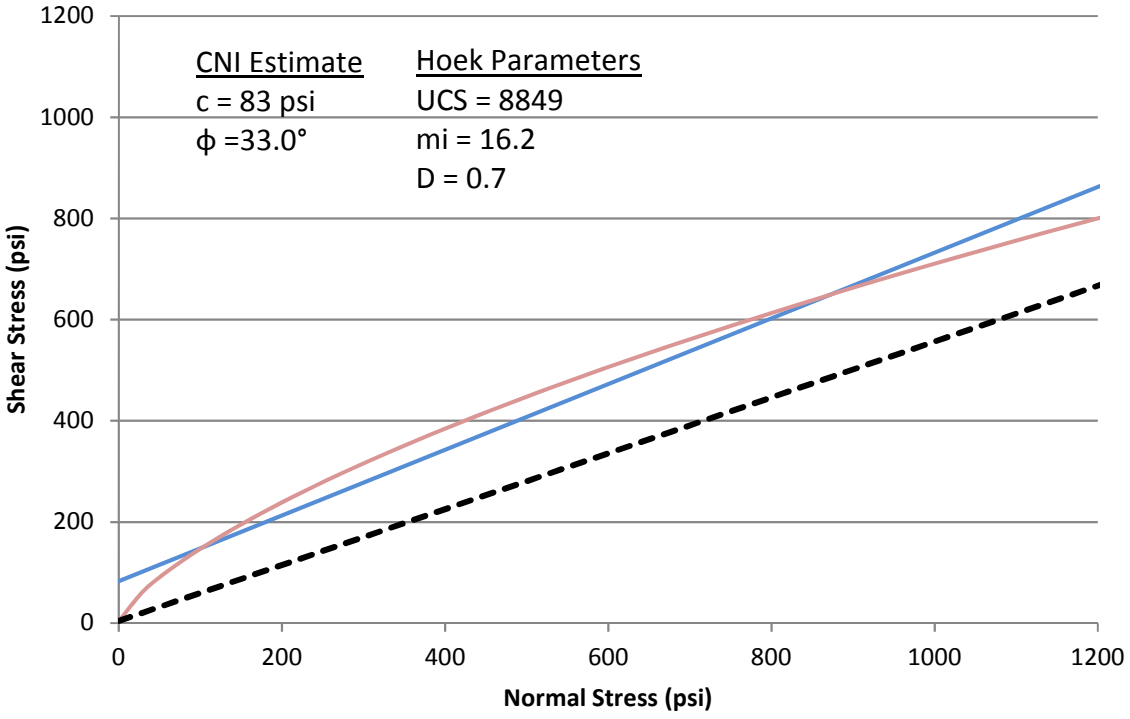


Rock-mass Strength Estimation, Phonolite (TPH), 70% RQD

CNI Method Rmass Estimate
Hoek-Brown Rmass Estimate (D=0.7)
Fracture Shear Strength

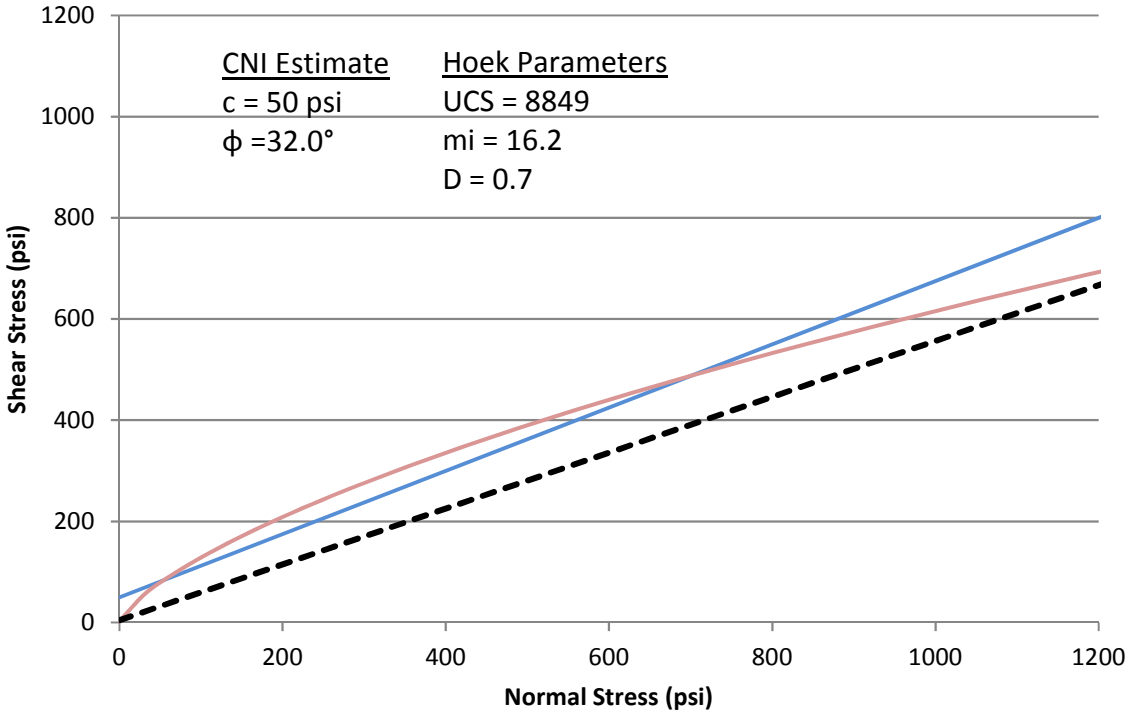


Rock-mass Strength Estimation, Phonolite (TPH), 50% RQD



Rock-mass Strength Estimation, Phonolite (TPH), 30% RQD

CNI Method Rmass Estimate
Hoek-Brown Rmass Estimate (D=0.7)
Fracture Shear Strength

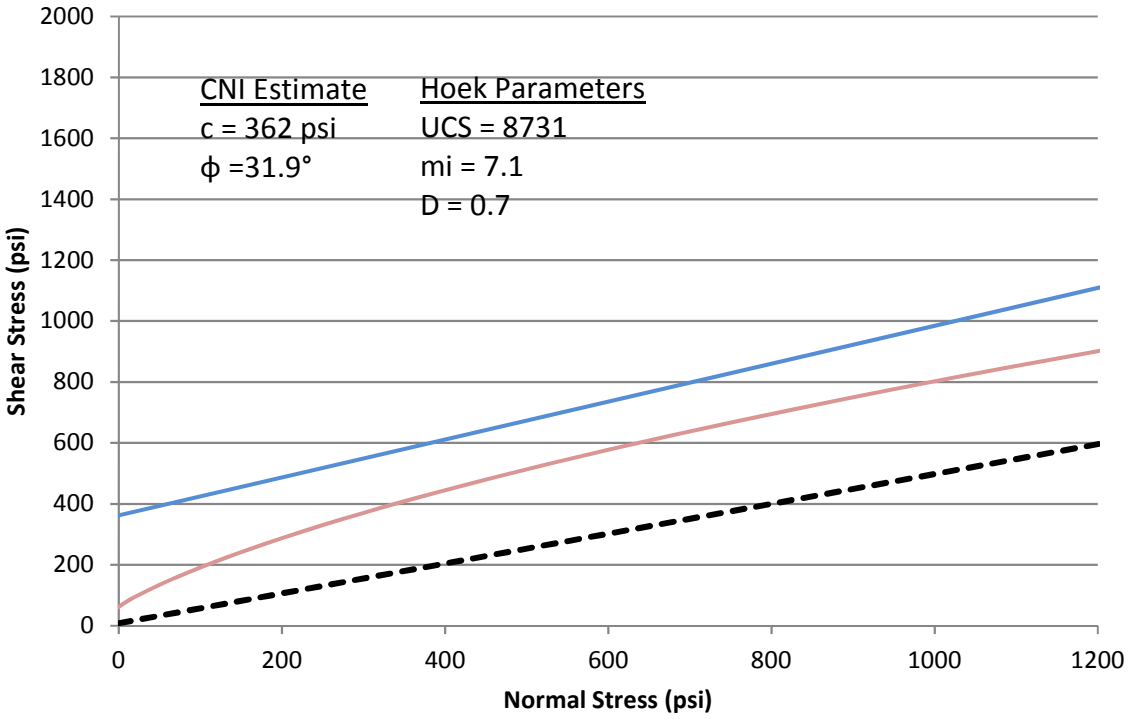


Rock-mass Strength Estimation, Phonolite (TPH), 10% RQD

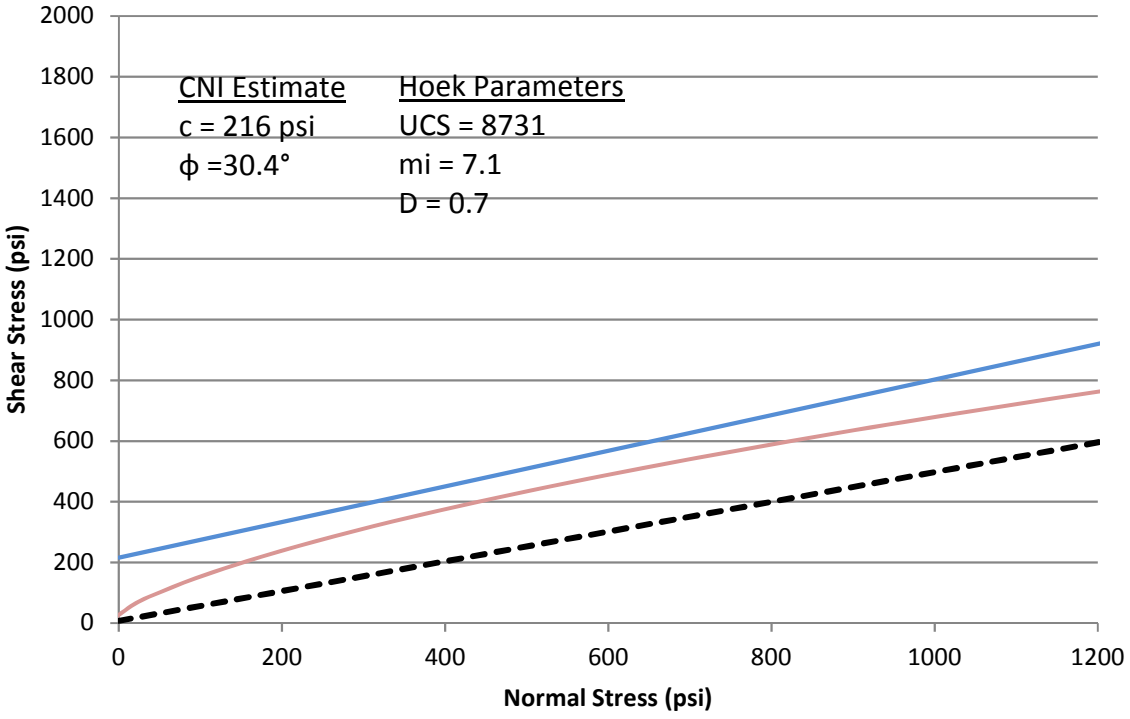
CNI Method Rmass Estimate

Hoek-Brown Rmass Estimate (D=0.7)

Fracture Shear Strength

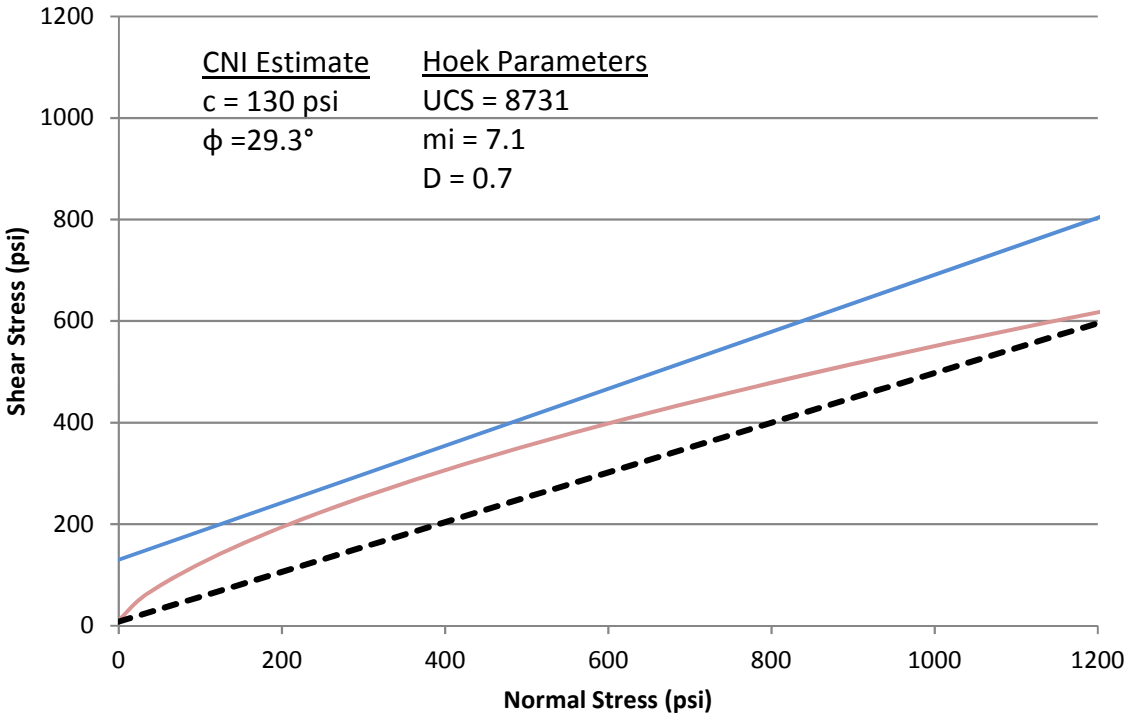


Rock-mass Strength Estimation, Lamprophyre (TLU), 90% RQD

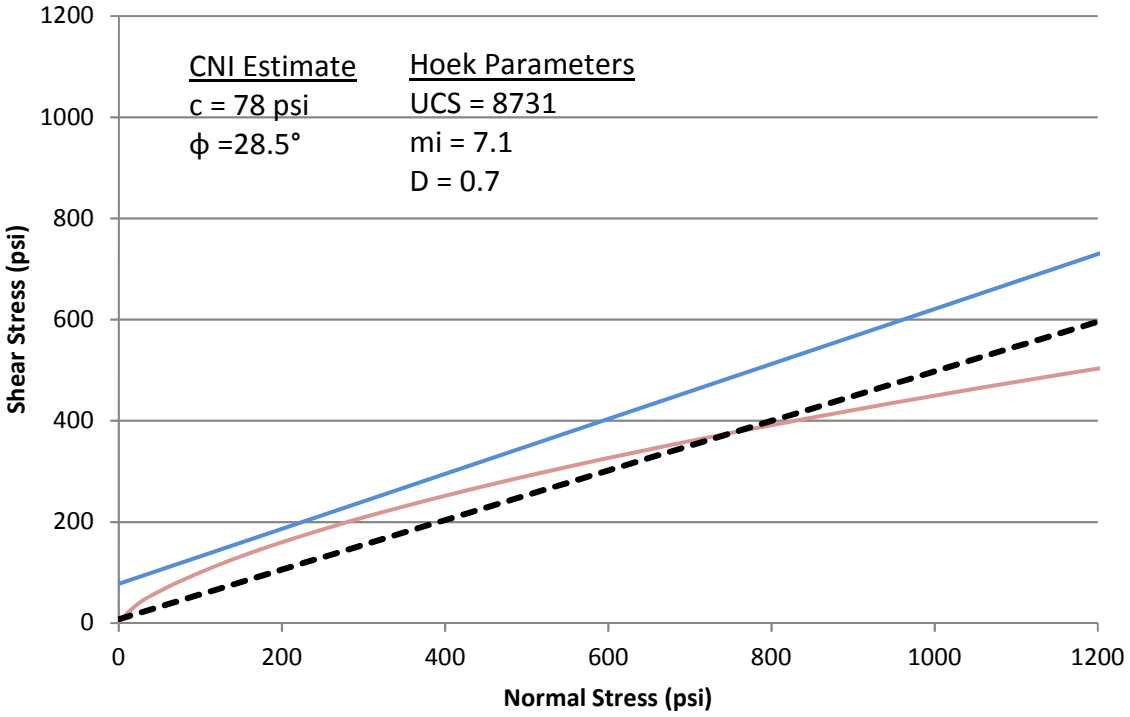


Rock-mass Strength Estimation, Lamprophyre (TLU), 70% RQD

CNI Method Rmass Estimate
Hoek-Brown Rmass Estimate (D=0.7)
Fracture Shear Strength

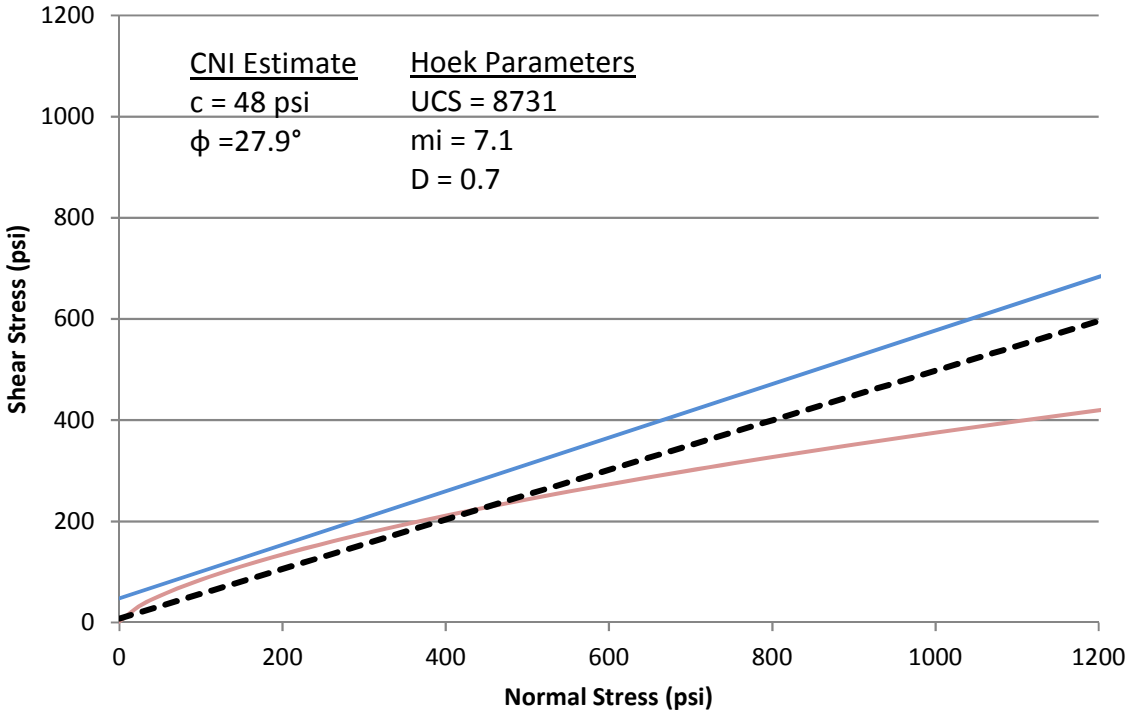


Rock-mass Strength Estimation, Lamprophyre (TLU), 50% RQD



Rock-mass Strength Estimation, Lamprophyre (TLU), 30% RQD

CNI Method Rmass Estimate
Hoek-Brown Rmass Estimate (D=0.7)
Fracture Shear Strength

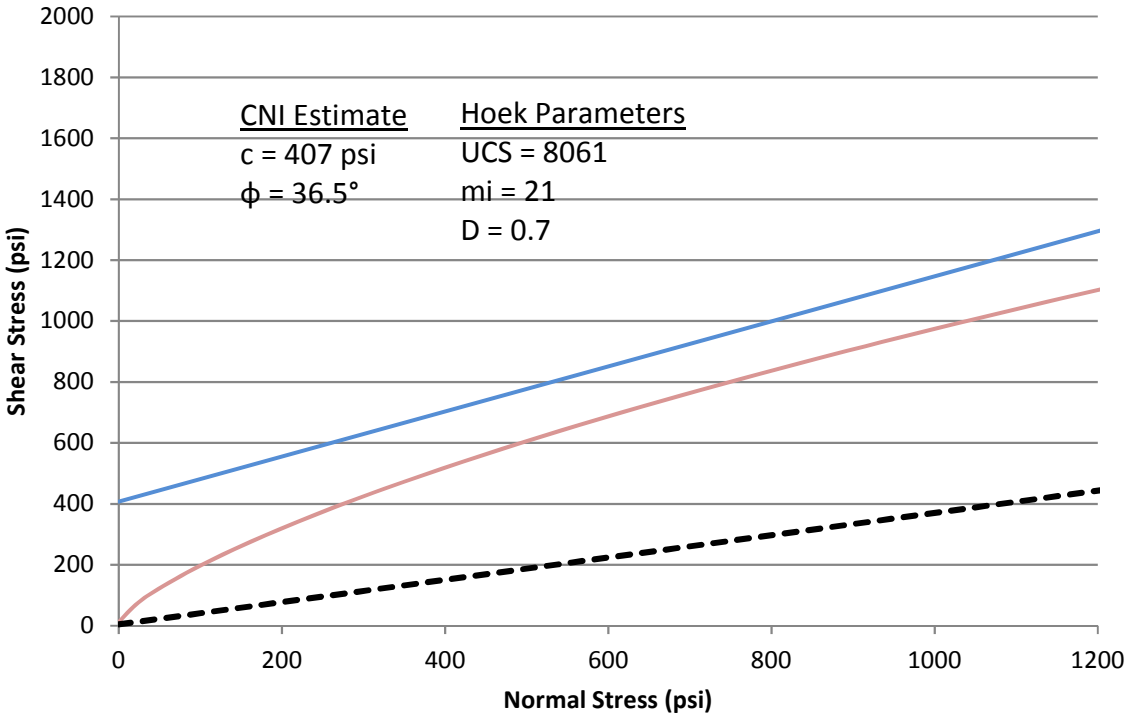


Rock-mass Strength Estimation, Lamprophyre (TLU), 10% RQD

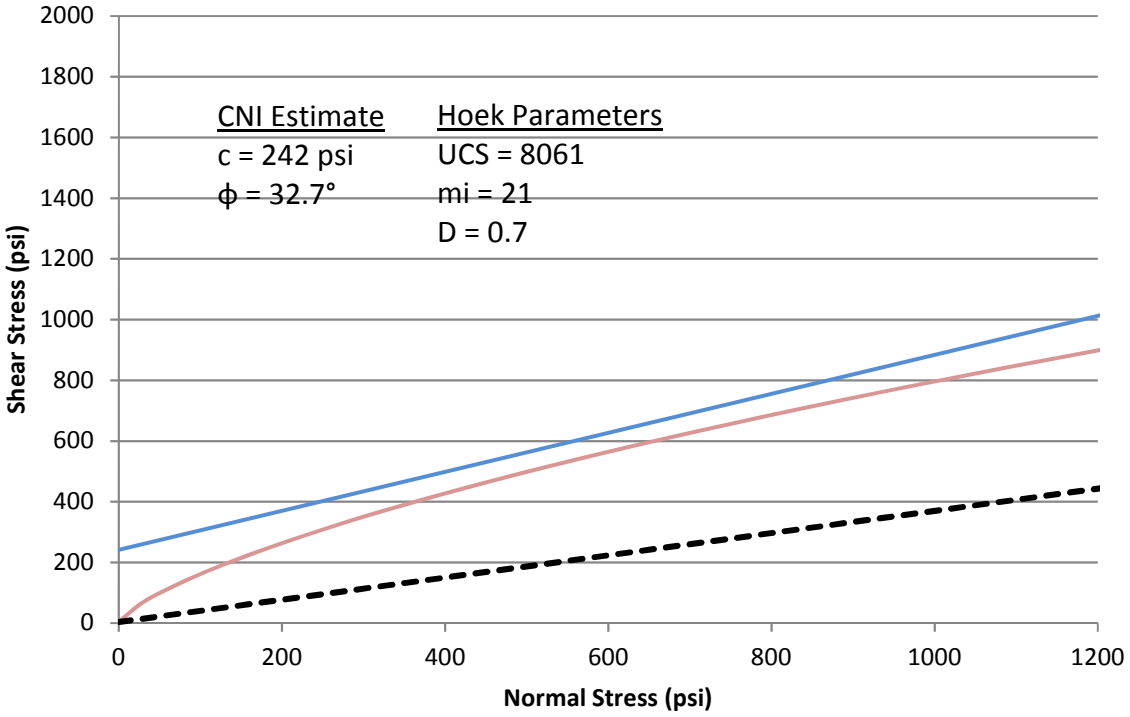
CNI Method Rmass Estimate

Hoek-Brown Rmass Estimate (D=0.7)

Fracture Shear Strength

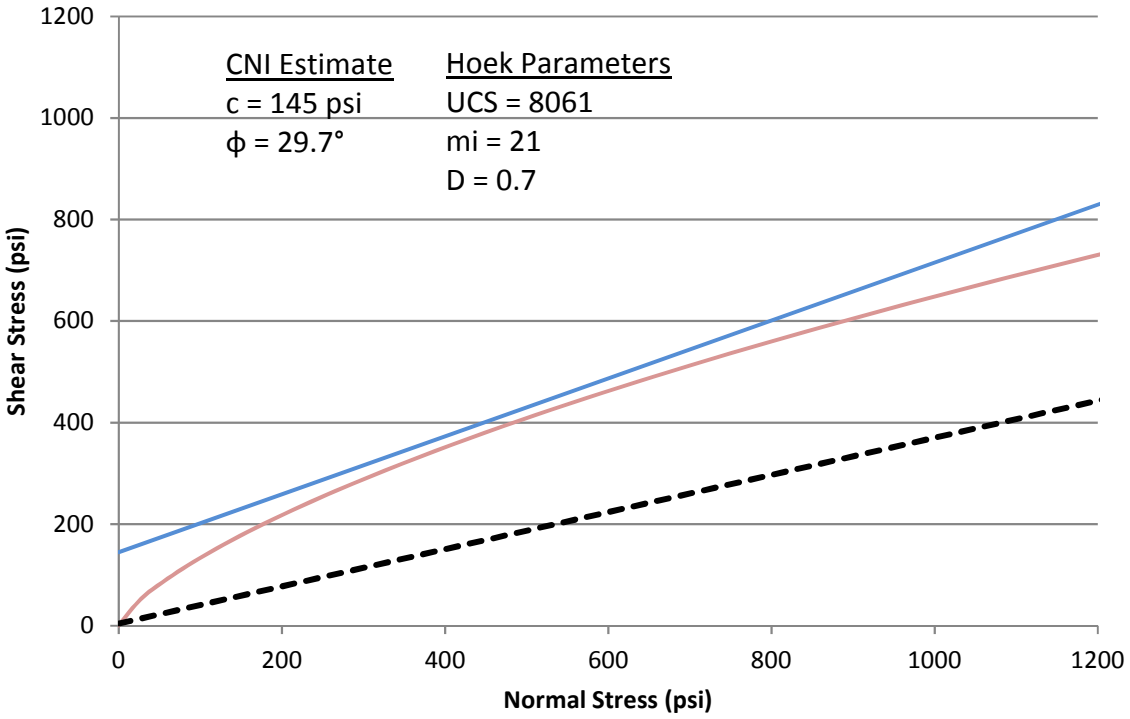


Rock-mass Strength Estimation, Precambrian Schist (XBS), 90% RQD

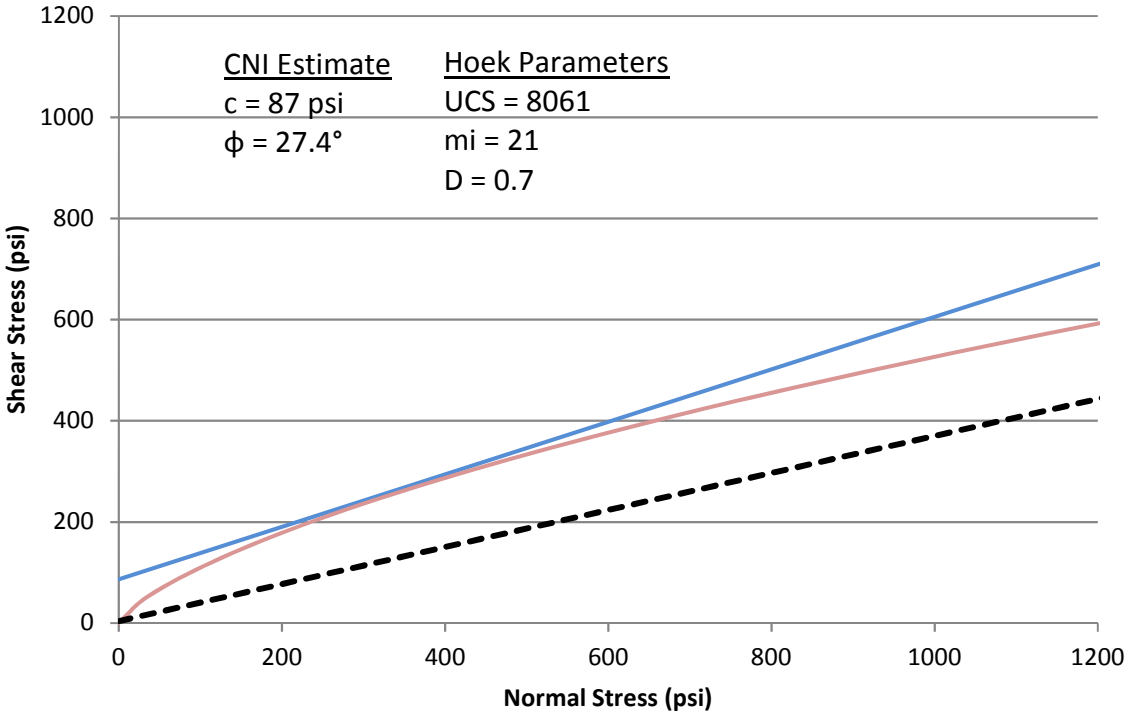


Rock-mass Strength Estimation, Precambrian Schist (XBS), 70% RQD

CNI Method Rmass Estimate
Hoek-Brown Rmass Estimate (D=0.7)
Fracture Shear Strength

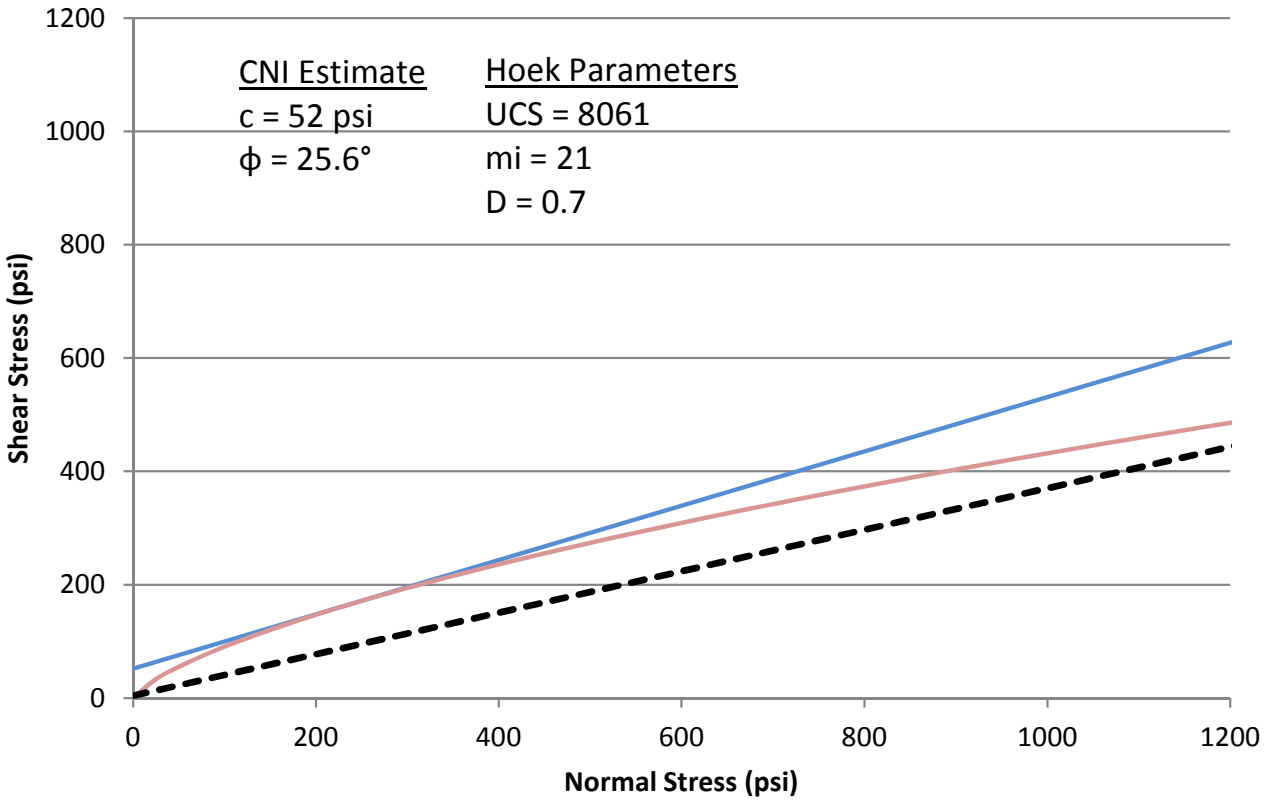


Rock-mass Strength Estimation, Precambrian Schist (XBS), 50% RQD



Rock-mass Strength Estimation, Precambrian Schist (XBS), 30% RQD

CNI Method Rmass Estimate
Hoek-Brown Rmass Estimate (D=0.7)
Fracture Shear Strength



Rock-mass Strength Estimation, Precambrian Schist (XBS), 10% RQD

CNI Method Rmass Estimate

Hoek-Brown Rmass Estimate (D=0.7)

Fracture Shear Strength

APPENDIX F

BACKBREAK DESIGN SETS

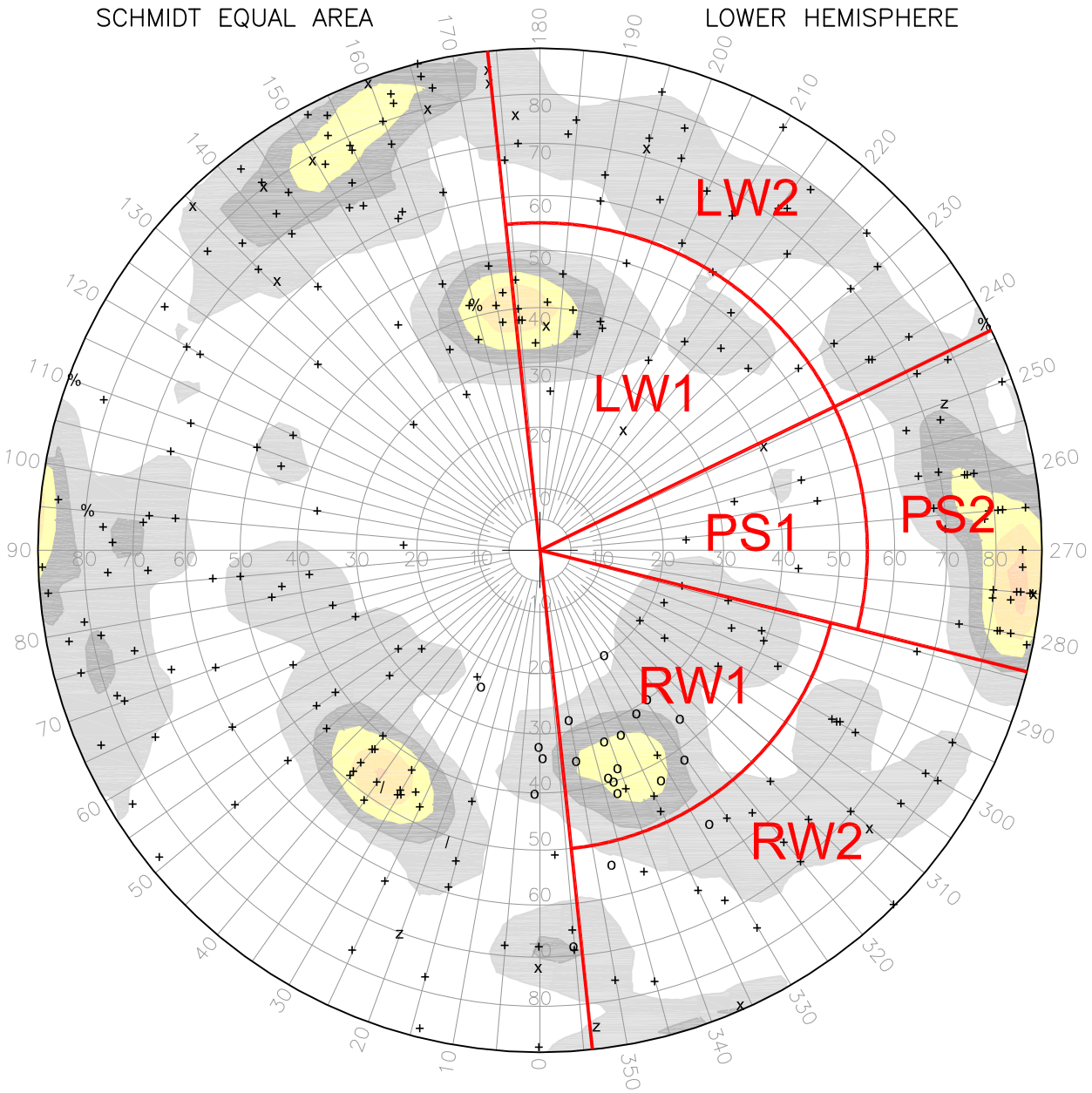


Figure 1F.
Backbreak Design Sets and Statistics
Sector 1, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 286

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	196.33	40.24	2.74	13.66	29.1%
LW2	205.31	71.22	2.73	12.89	52.7%
PS1	259.33	38.83	2.76	4.98	9.1%
PS2	266.48	79.55	3.31	14.60	58.2%
RW1	320.96	34.96	2.94	28.82	49.1%
RW2	319.07	68.61	3.15	16.00	41.8%

Acad File
\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 01F - SECTOR 1 XGD.DWG

10/26/2015 8:07 AM

File:
XGD.met

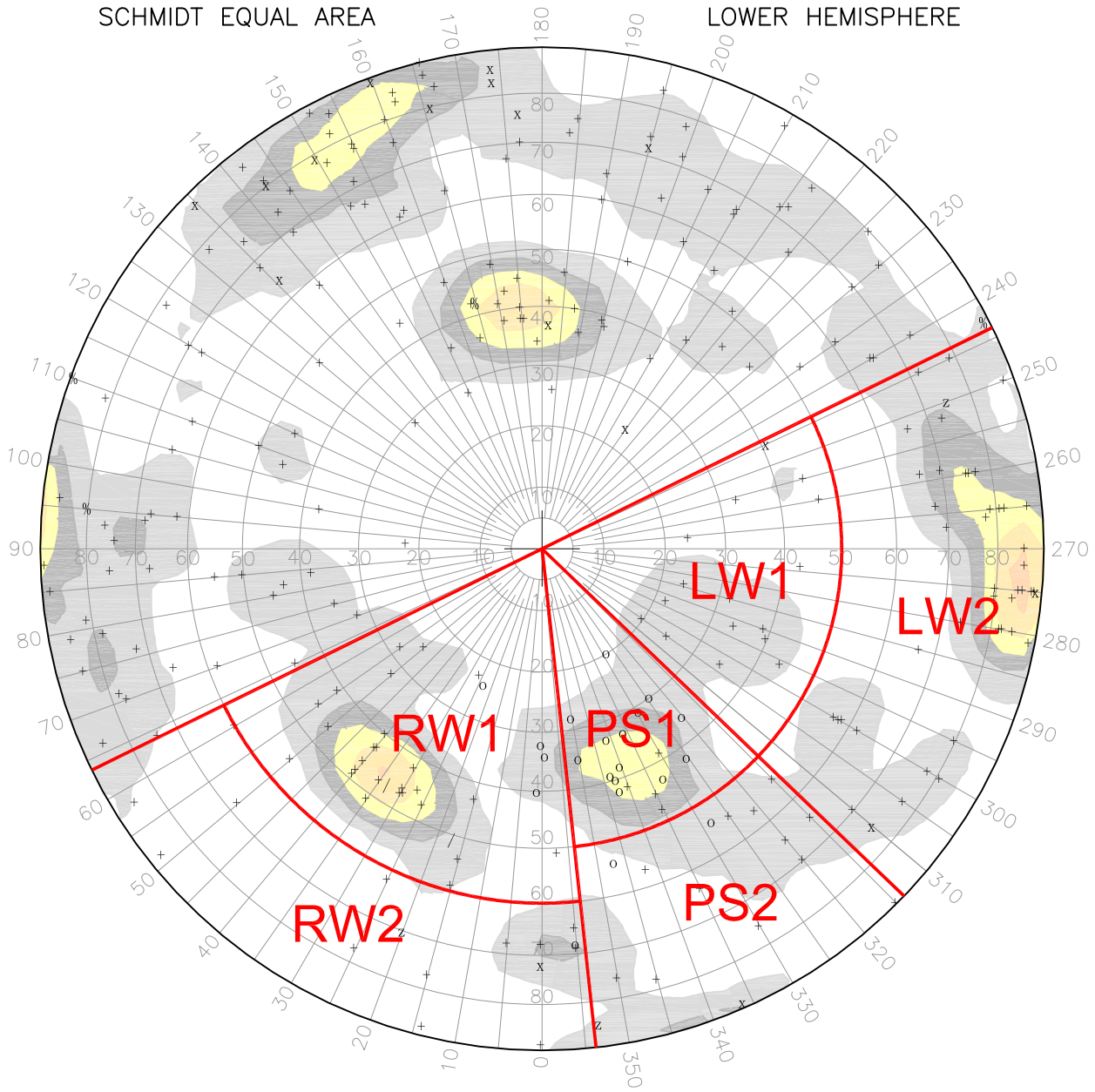


Figure 2F.
Backbreak Design Sets and Statistics
Sector 2, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 286

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	281.31	34.25	3.02	13.18	23.6%
LW2	274.98	77.00	3.34	13.04	72.7%
PS1	335.67	36.89	2.82	35.23	32.7%
PS2	331.12	68.12	2.95	21.20	27.3%
RW1	31.27	42.43	4.86	25.61	47.3%
RW2	21.88	73.35	4.28	44.69	27.3%

Acad File
\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 02F - SECTOR 2 XGD.DWG

10/26/2015 8:03 AM

File:
XGD.met

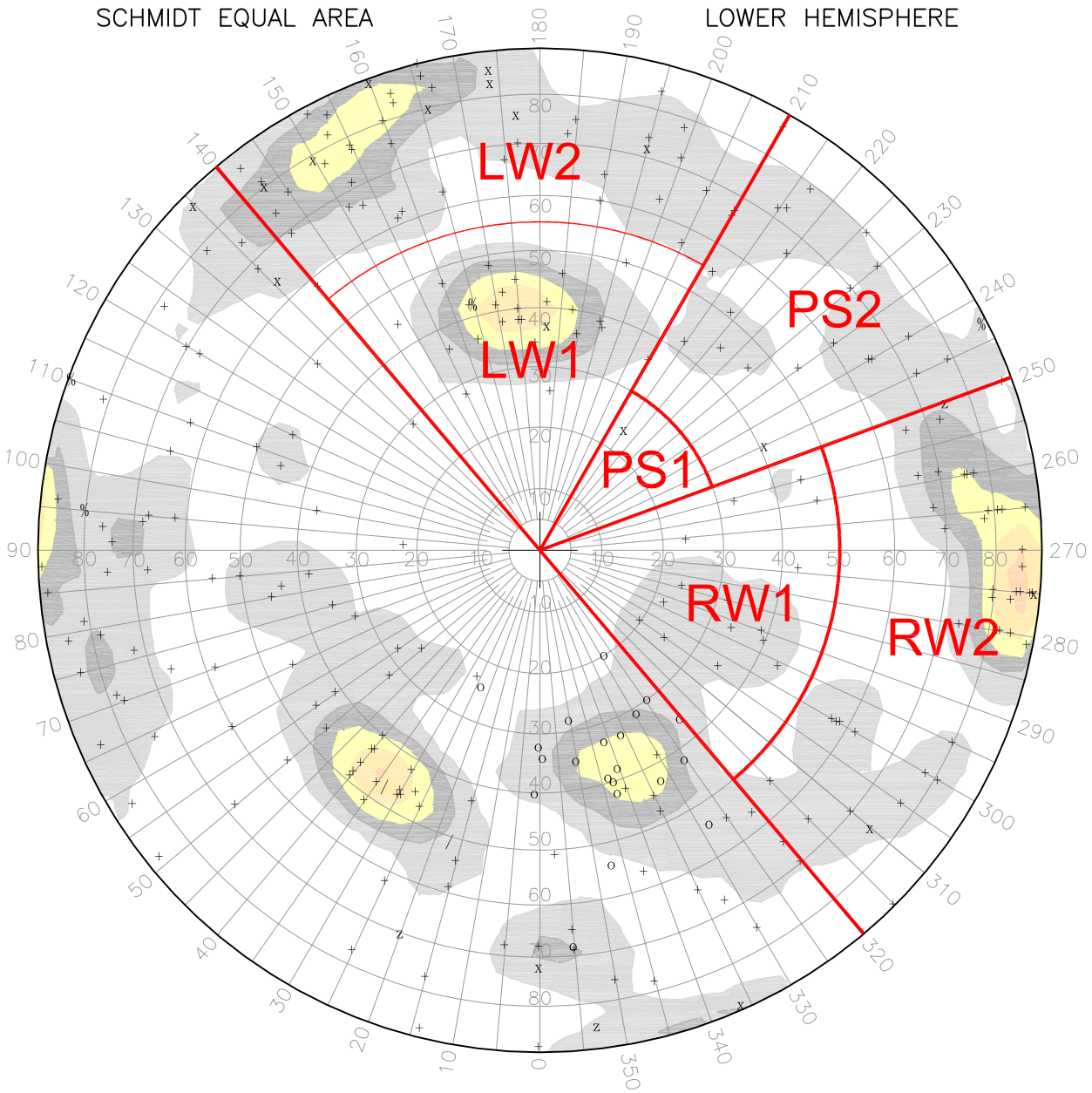


Figure 3F.
Backbreak Design Sets and Statistics
Sector 3, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 286

FISHER CONCENTRATION:

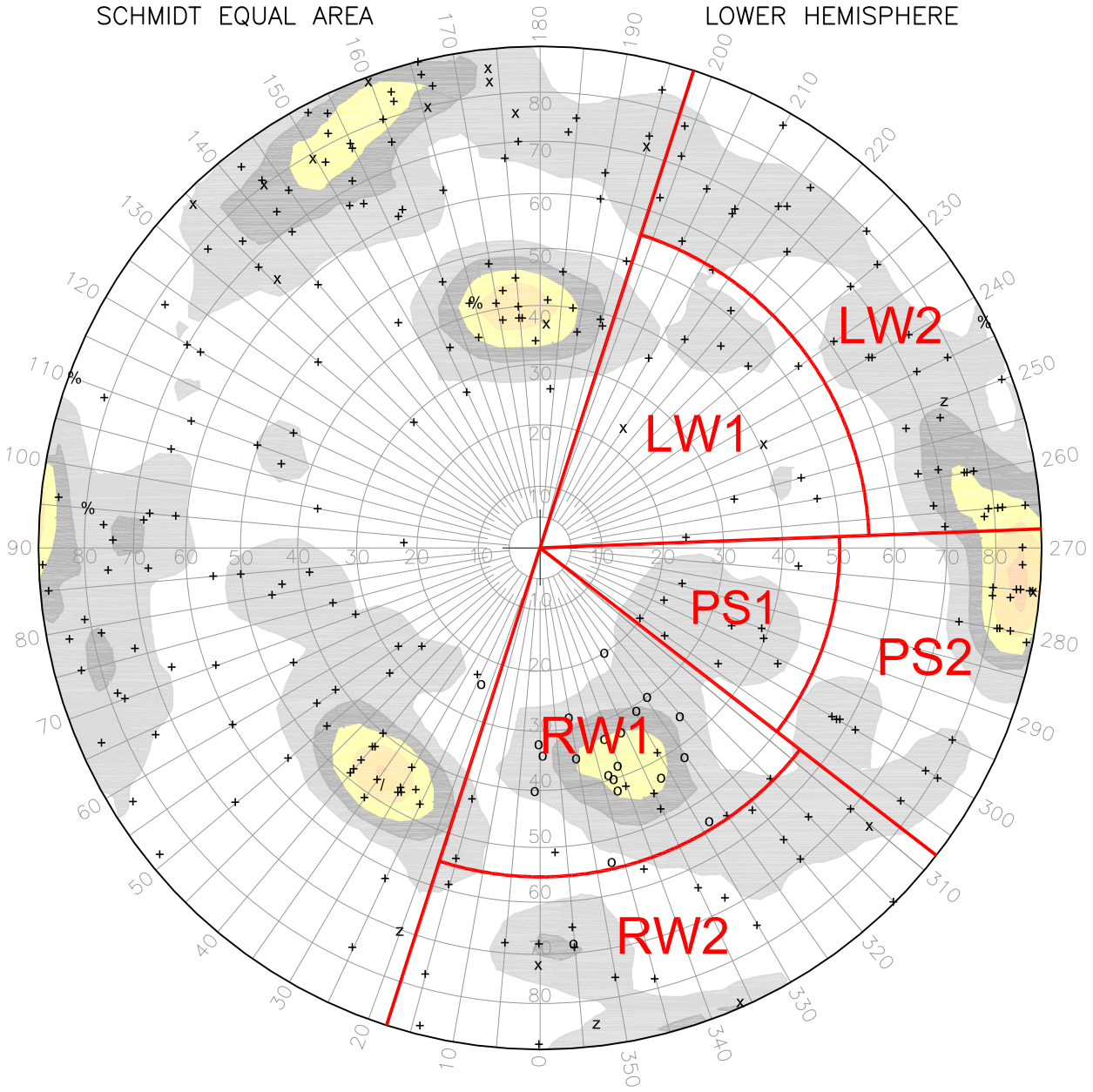
0.0% ~ 1.0%		4.0% ~ 5.0%	
1.0% ~ 2.0%		5.0% ~ 6.0%	
2.0% ~ 3.0%		6.0% ~ 7.0%	
3.0% ~ 4.0%			

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	176.72	39.48	3.00	10.96	40.0%
LW2	169.84	75.02	2.71	10.47	65.5%
PS1	227.50	46.33	3.48	19.45	9.1%
PS2	229.36	70.57	2.95	19.83	25.5%
RW1	286.00	33.94	2.92	15.04	25.5%
RW2	280.72	76.21	3.35	13.60	72.7%

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10/26/2015 9:14 AM

File:
XGD.met



CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 286

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	235.58	40.58	3.05	12.17	18.2%
LW2	237.05	72.53	2.88	13.70	61.8%
PS1	292.64	32.55	3.19	16.23	16.4%
PS2	284.58	78.42	3.83	15.10	38.2%
RW1	342.46	39.46	3.65	40.76	47.3%
RW2	341.04	71.04	3.44	33.05	41.8%

Acad File
\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 04F - SECTOR 4 XGD.DWG

10/26/2015 9:14 AM

File: XGD.met

Figure 4F.
Backbreak Design Sets and Statistics
Sector 4, Pre-Cambrian

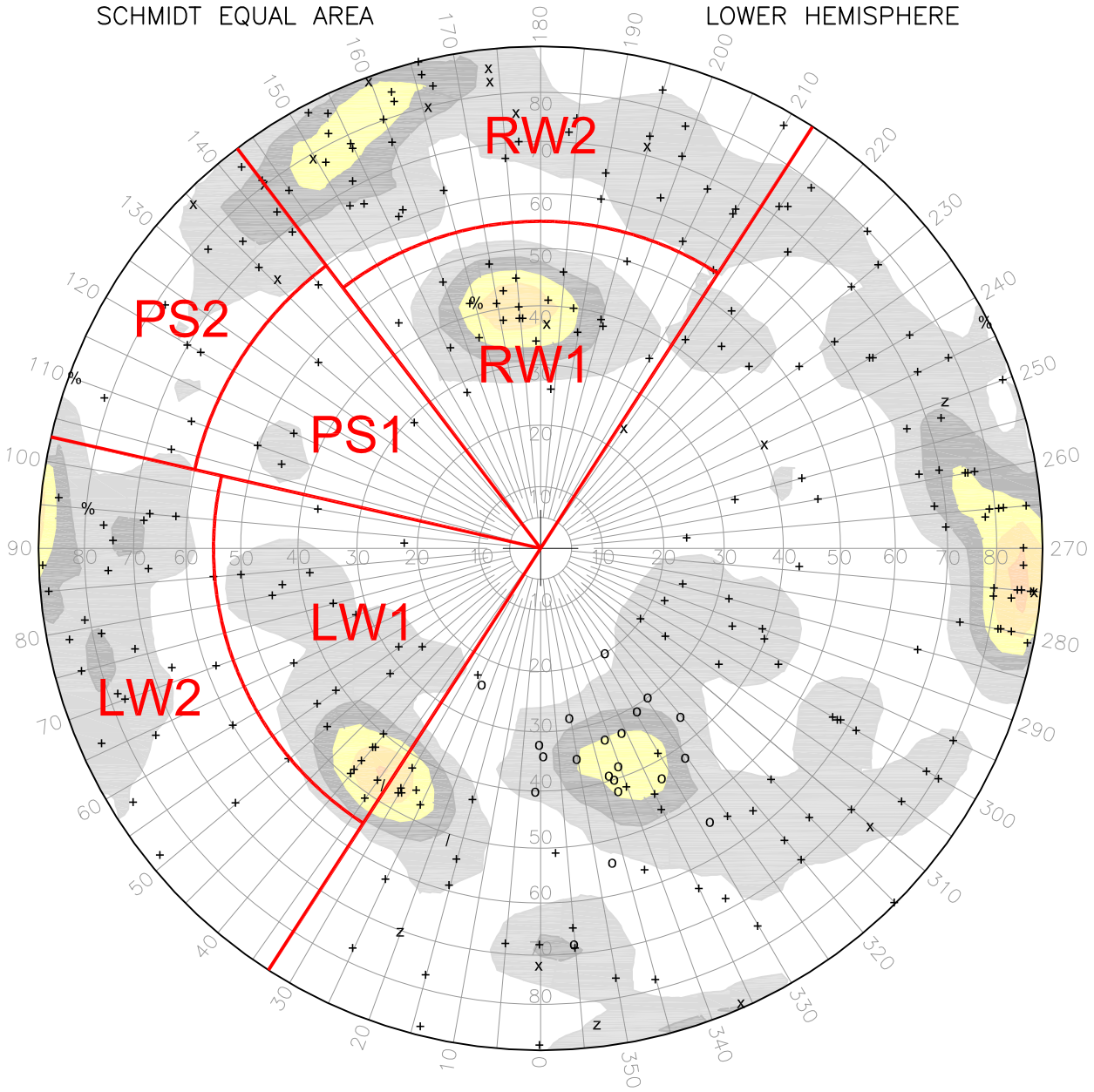


Figure 5F.
Backbreak Design Sets and Statistics
Sector 5, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 286

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	59.04	40.48	5.43	26.51	38.2%
LW2	76.59	74.07	2.77	20.13	45.5%
PS1	123.00	45.83	3.98	22.42	10.9%
PS2	127.64	73.14	2.89	11.80	25.5%
RW1	176.72	39.48	3.00	10.96	40.0%
RW2	173.22	74.87	2.74	11.62	63.6%

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\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 05F - SECTOR 5 XGD.DWG

10/26/2015 9:15 AM

File:
XGD.met

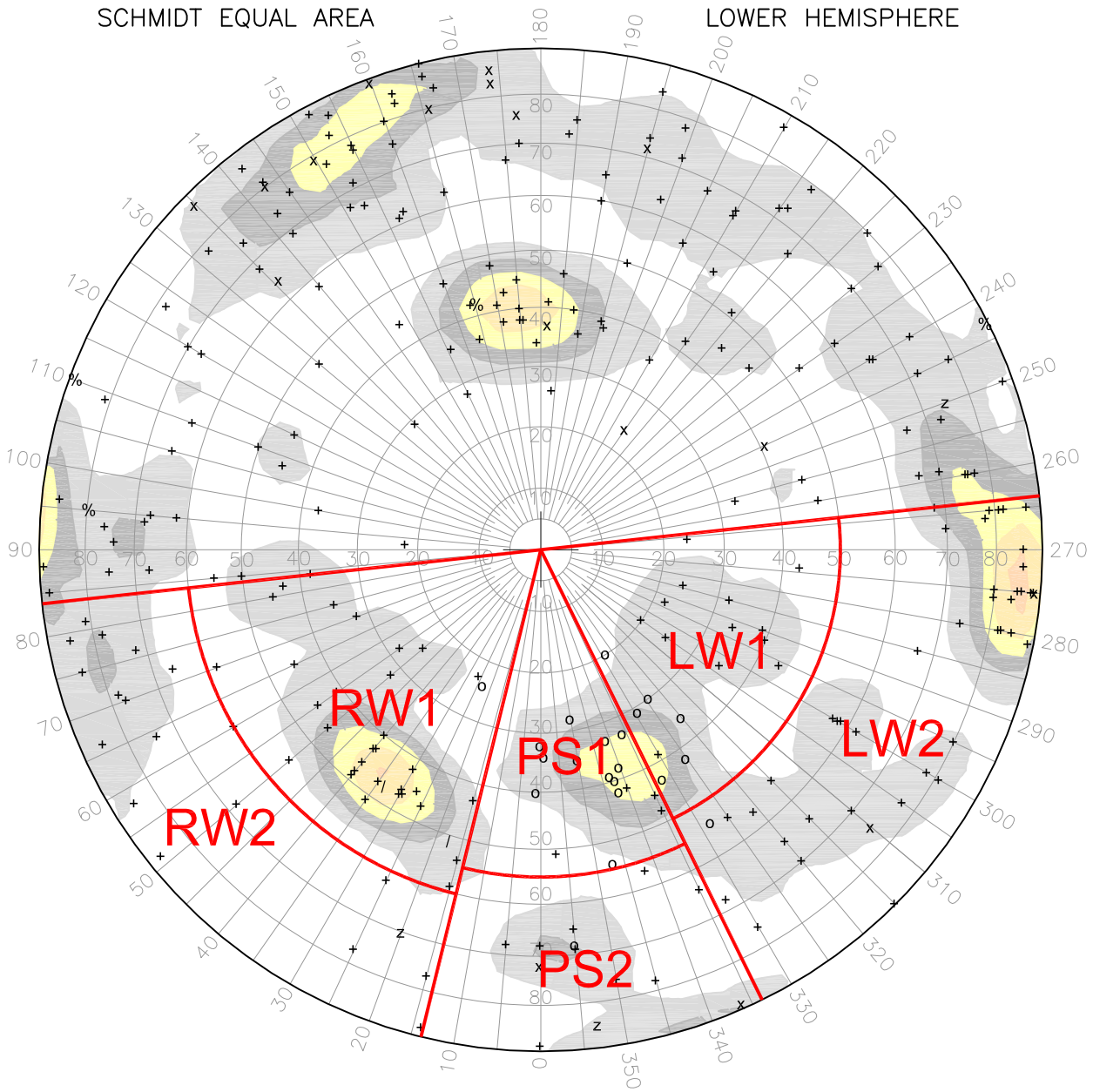


Figure 6F.
Backbreak Design Sets and Statistics
Sector 6, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 286

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	303.84	32.79	2.85	26.63	30.9%
LW2	291.35	75.05	3.44	14.33	65.5%
PS1	346.12	39.62	3.05	30.93	29.1%
PS2	351.62	72.92	3.67	18.87	21.8%
RW1	44.45	42.79	5.16	24.50	50.9%
RW2	55.32	76.53	3.11	40.35	32.7%

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File:
XGD.met

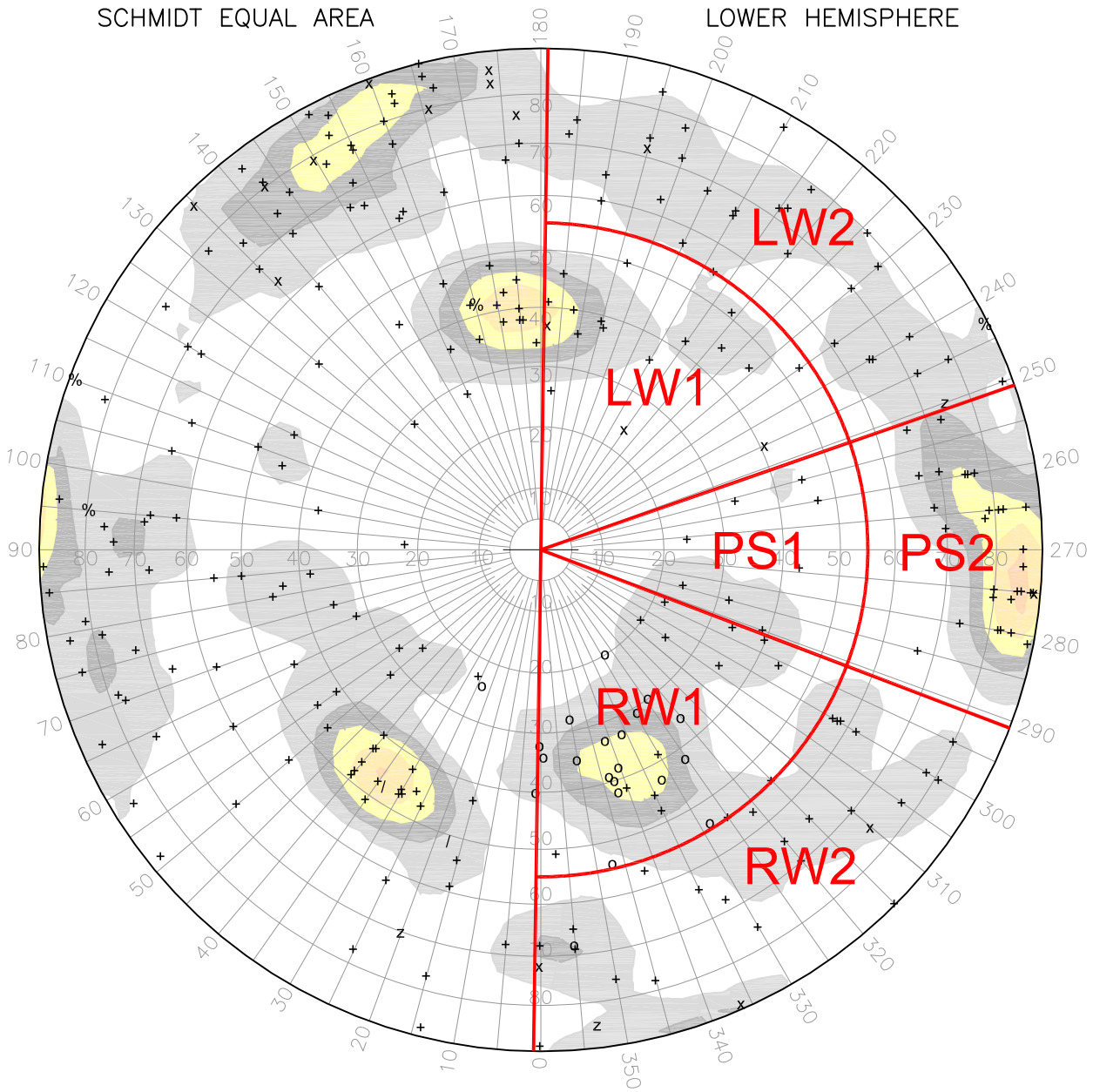


Figure 7F.
Backbreak Design Sets and Statistics
Sector 7, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 286

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	205.24	40.65	2.94	11.80	25.5%
LW2	215.58	71.32	2.87	13.03	52.7%
PS1	271.25	35.88	2.70	5.62	12.7%
PS2	269.63	79.27	3.23	15.00	52.7%
RW1	330.32	37.06	3.06	33.06	56.4%
RW2	326.42	70.23	3.45	13.91	47.3%

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\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 07F - SECTOR 7 XGD.DWG

11/5/2015 11:04 AM

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XGD.met

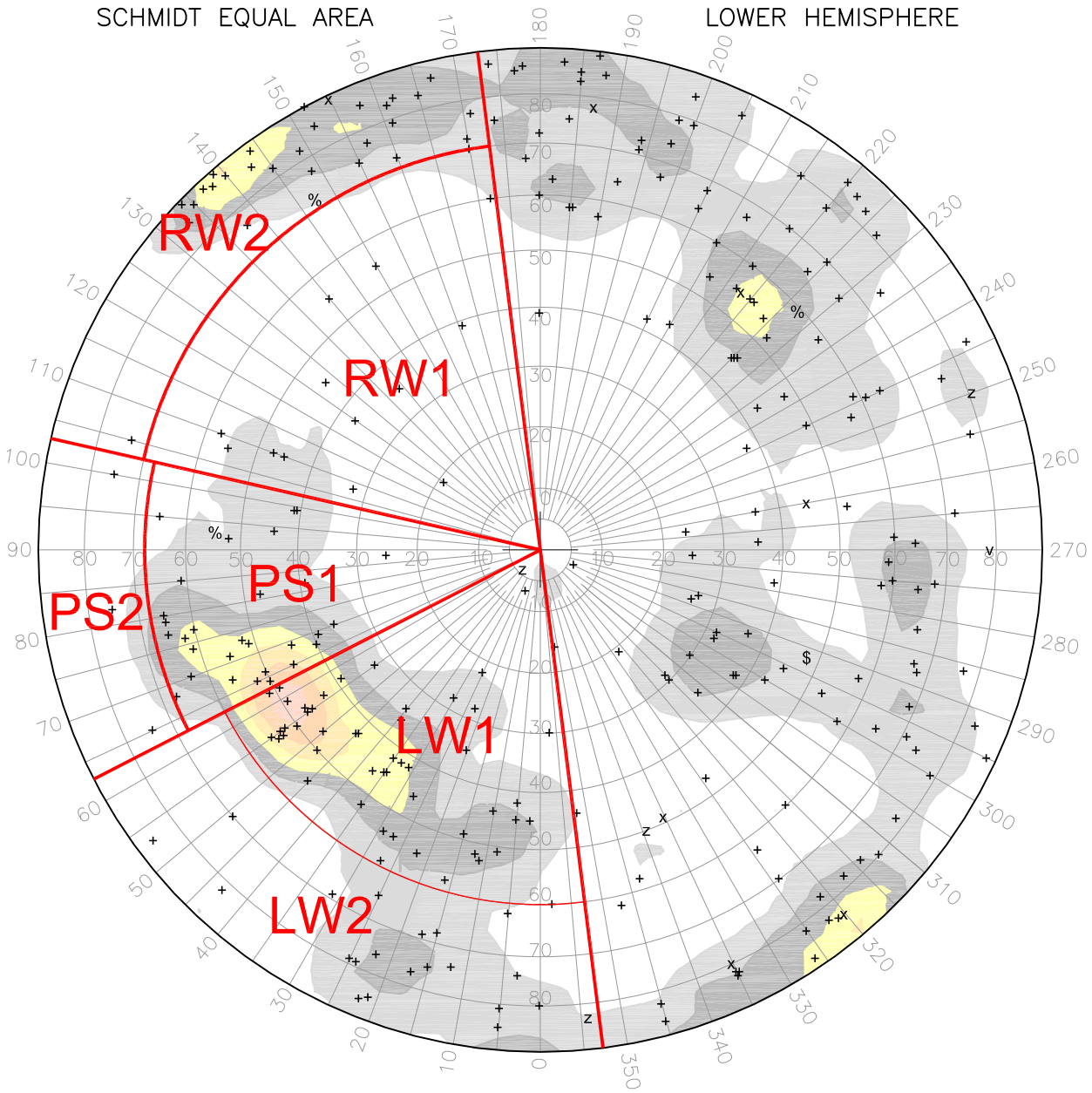


Figure 8F.
Backbreak Design Sets and Statistics
Sector 8, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 290

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	35.32	44.08	6.81	16.40	76.7%
LW2	18.23	75.68	7.18	21.12	36.7%
PS1	77.03	51.48	5.03	12.01	45.0%
PS2	82.33	74.67	3.80	13.27	5.0%
RW1	129.69	44.69	9.39	45.23	20.0%
RW2	149.83	82.10	3.76	5.58	45.0%

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\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 08F - SECTOR 8 TPH.DWG

11/5/2015 11:05 AM

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TPH.met

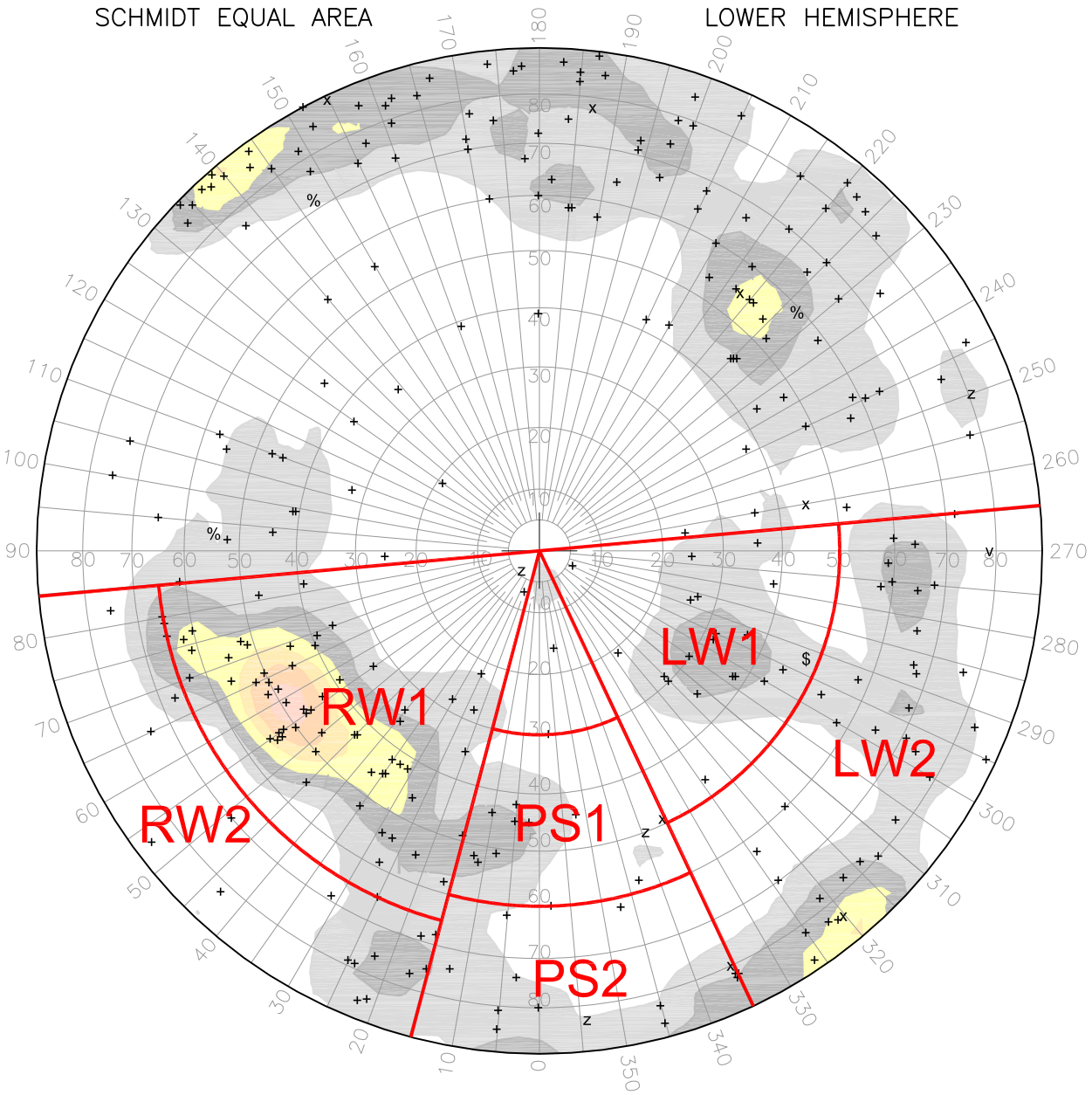


Figure 9F.
Backbreak Design Sets and Statistics
Sector 9, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 290

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	300.00	33.25	8.18	24.47	31.7%
LW2	301.79	72.18	5.54	8.46	61.7%
PS1	0.36	46.73	9.63	15.51	16.7%
PS2	358.09	75.55	9.52	33.29	18.3%
RW1	50.48	45.98	5.57	15.06	88.3%
RW2	41.50	73.85	4.50	9.60	31.7%

Acad File
\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 09F - SECTOR 9 TPH.DWG

11/5/2015 11:05 AM

File:
TPH.met

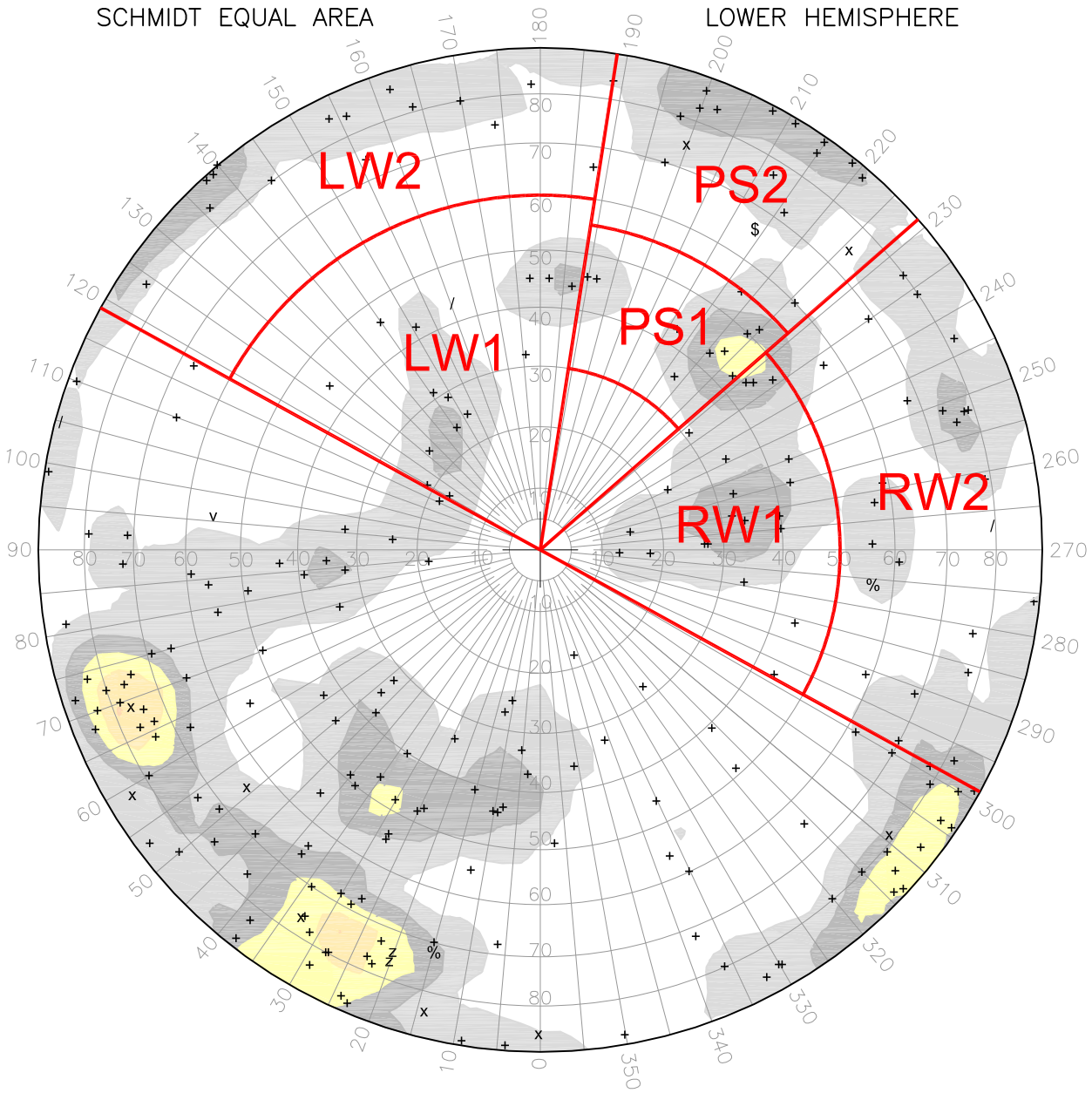


Figure 10F.
Backbreak Design Sets and Statistics
Sector 10, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 241

FISHER CONCENTRATION:

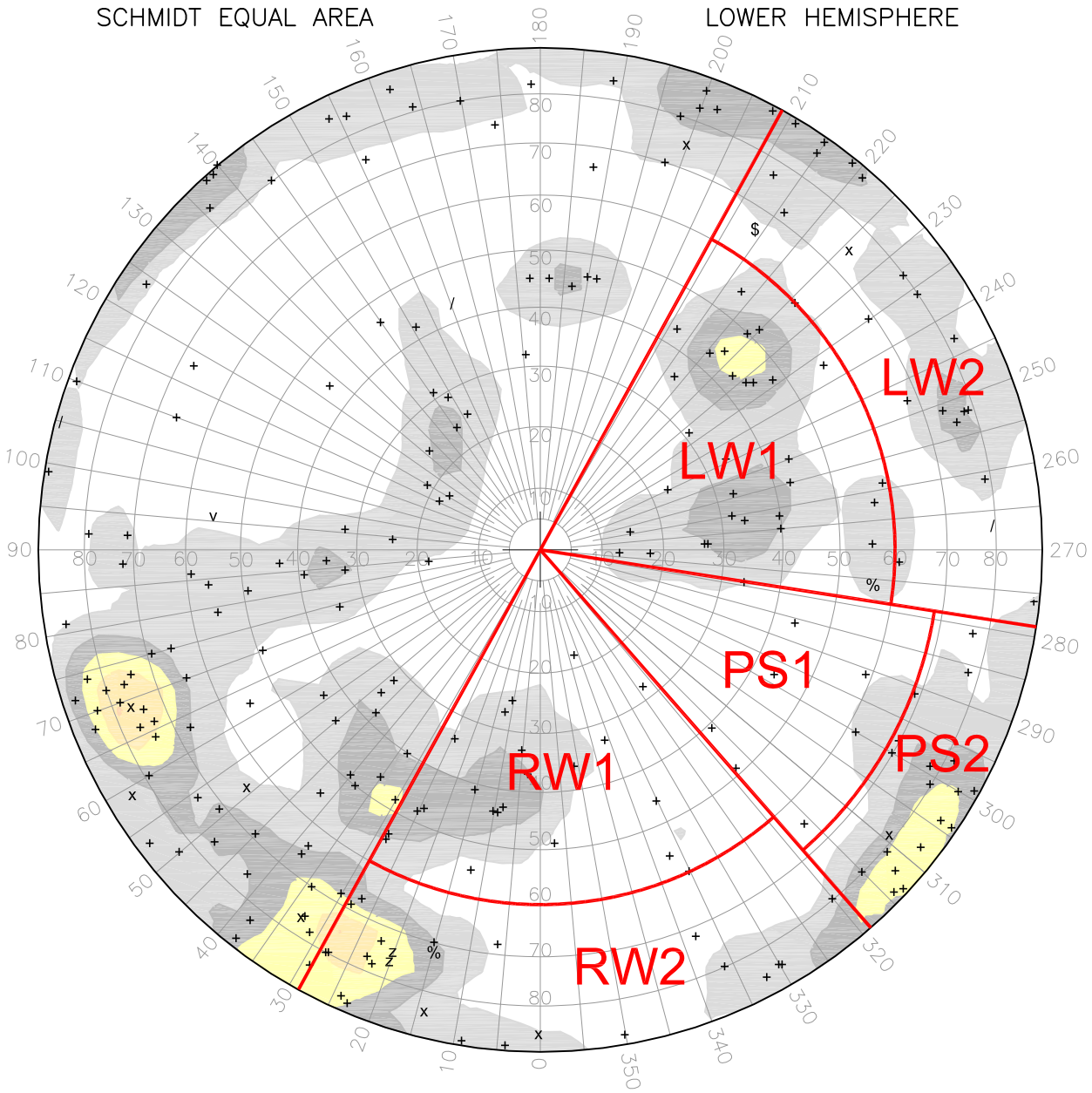
0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	300.00	33.25	8.18	24.47	31.7%
LW2	301.79	72.18	5.54	8.46	61.7%
PS1	0.36	46.73	9.63	15.51	16.7%
PS2	358.09	75.55	9.52	33.29	18.3%
RW1	50.48	45.98	5.57	15.06	88.3%
RW2	41.50	73.85	4.50	9.60	31.7%

Acad File
\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 10F - SECTOR 10 TPX.DWG

10/26/2015 9:18 AM

File:
TBX.met



CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 241

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	246.45	39.39	4.68	19.76	53.7%
LW2	236.81	78.10	3.20	12.62	37.0%
PS1	303.57	52.00	6.70	55.10	13.0%
PS2	302.21	81.16	4.52	9.52	35.2%
RW1	3.76	40.62	5.01	21.33	38.9%
RW2	5.12	79.04	3.78	17.16	44.4%

Acad File
\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 11F - SECTOR 11 TPX.DWG

10/26/2015 9:18 AM

File:
TBX.met

Figure 11F.
Backbreak Design Sets and Statistics
Sector 11, Pre-Cambrian

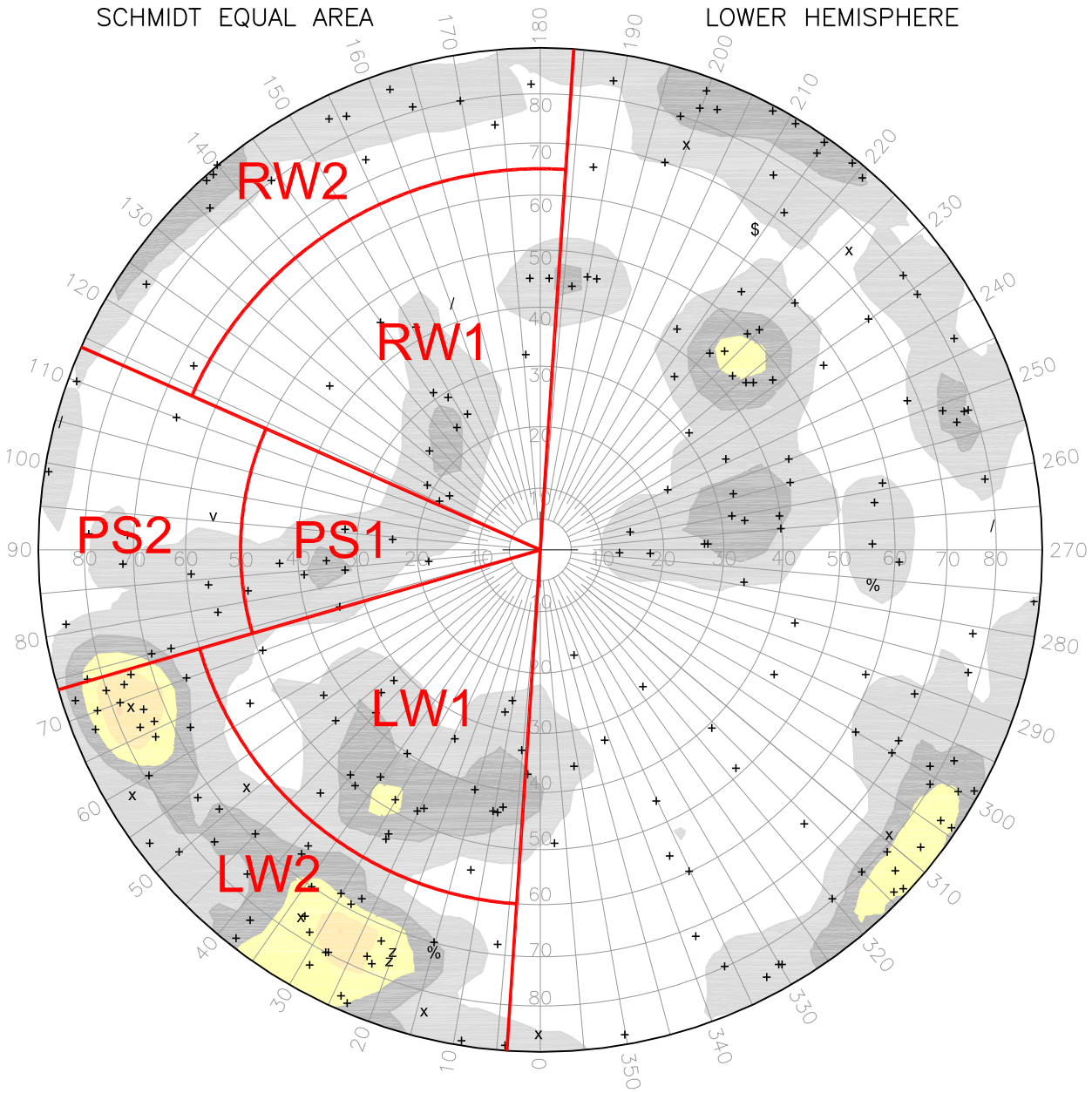


Figure 12F.
Backbreak Design Sets and Statistics
Sector 12, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 241

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP		MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	32.63	43.26		4.22	21.81	48.1%
LW2	43.24	76.75		2.63	14.34	81.5%
PS1	87.25	34.00		4.53	24.41	14.8%
PS2	89.25	71.17	1	3.14	28.59	22.2%
RW1	145.86	31.64	1	5.20	21.16	25.9%
RW2	150.27	81.93		3.54	12.79	25.9%

Acad File
\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 12F - SECTOR 12 TPX.DWG

10/26/2015 9:18 AM

File:
TBX.met

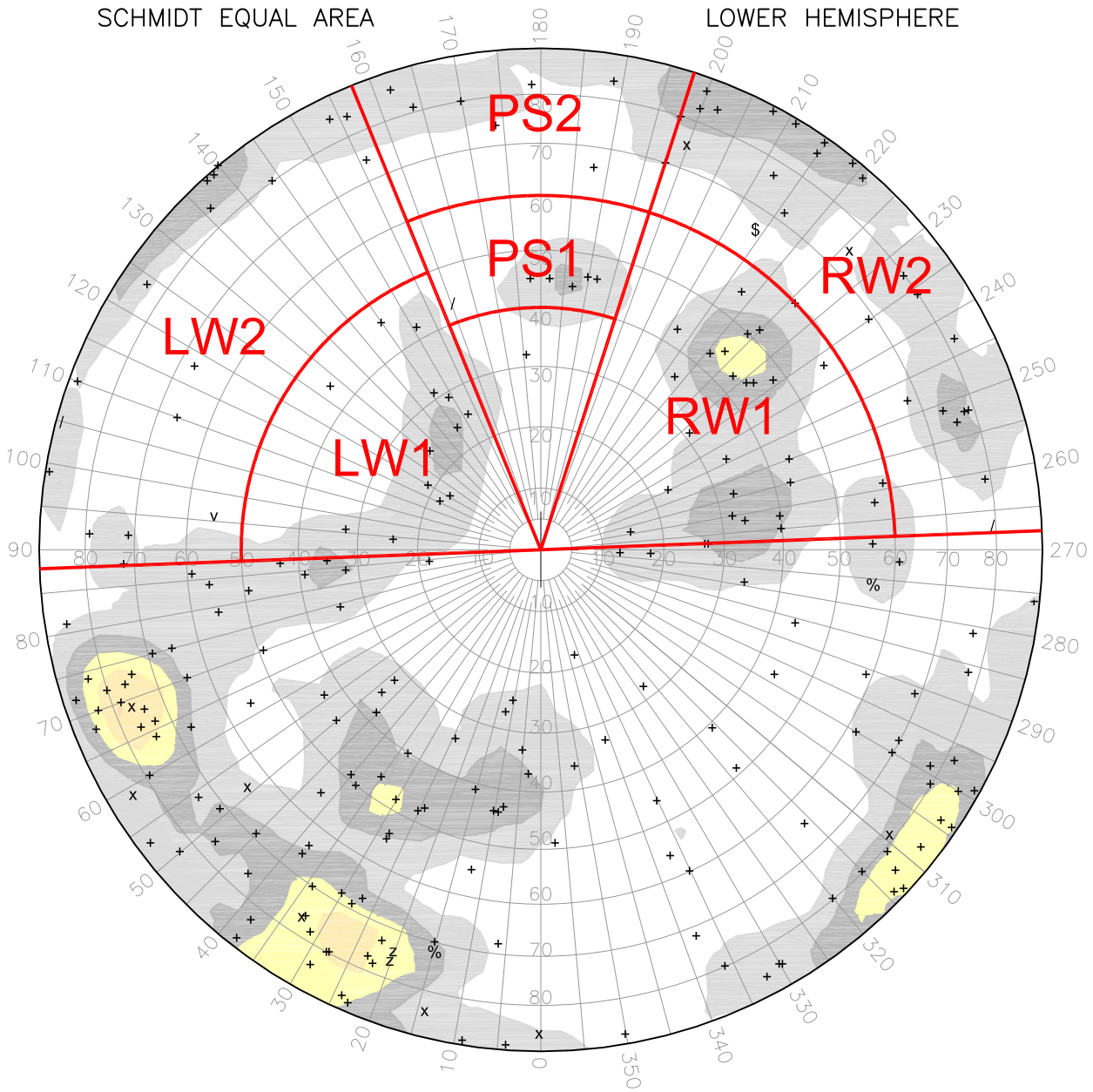


Figure 13F.
Backbreak Design Sets and Statistics
Sector 13, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 241

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	130.46	29.00	5.33	20.93	24.1%
LW2	124.75	80.69	4.11	22.95	27.8%
PS1	185.80	45.20	3.07	11.92	9.3%
PS2	175.14	79.00	2.34	20.94	13.0%
RW1	242.52	40.74	4.45	19.89	48.1%
RW2	224.27	79.15	2.66	11.28	44.4%

Acad File
\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 13F - SECTOR 13 TPX.DWG

10/26/2015 9:57 AM

File:
TBX.met

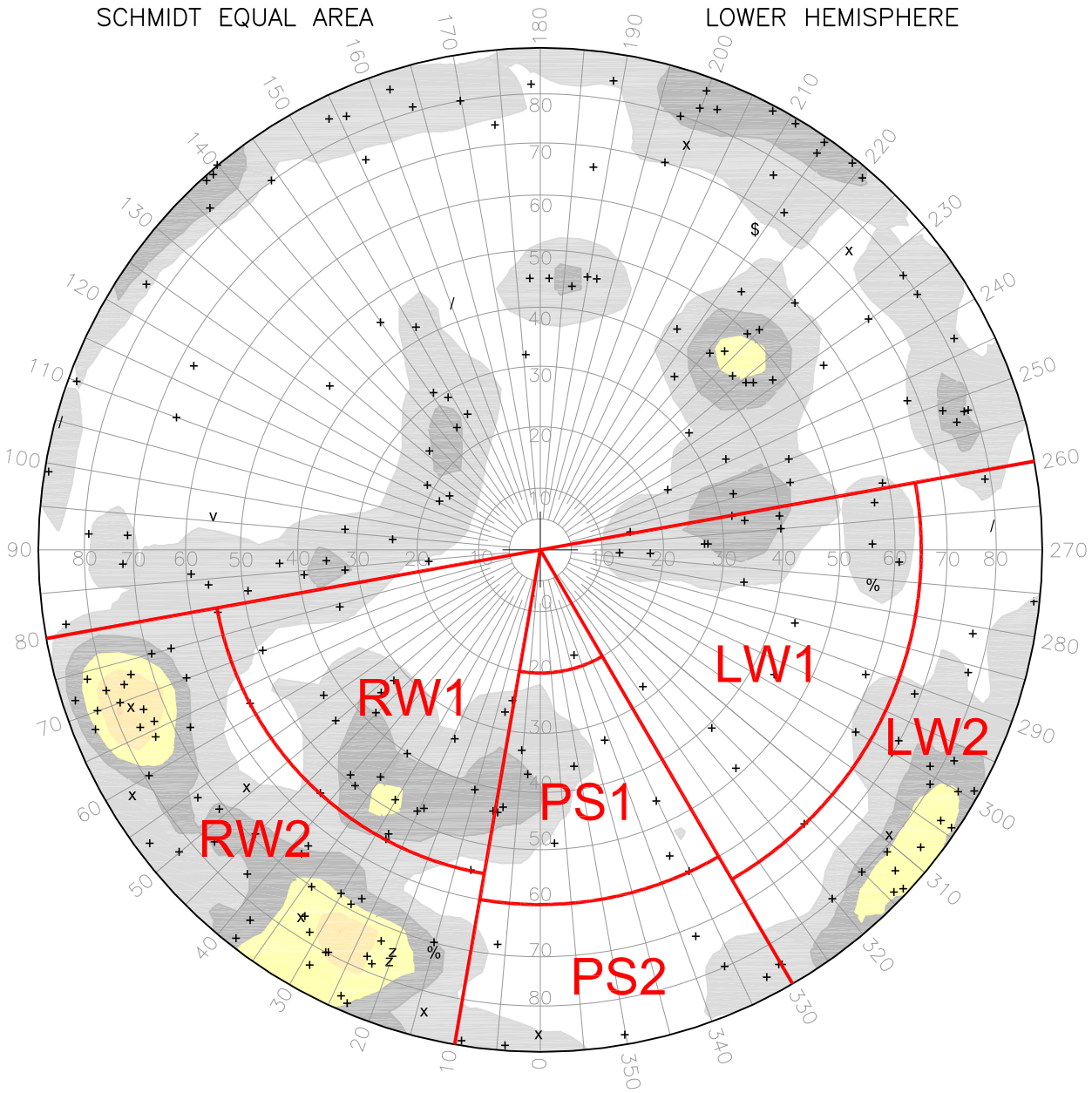


Figure 14F.
Backbreak Design Sets and Statistics
Sector 14, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 241

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	281.21	40.32	6.10	29.31	31.5%
LW2	303.00	81.00	4.22	9.84	46.3%
PS1	354.00	41.89	5.08	29.01	16.7%
PS2	350.00	79.78	3.51	19.91	14.8%
RW1	35.75	41.40	3.93	13.39	37.0%
RW2	46.53	74.13	2.84	15.44	85.2%

Acad File
\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 14F - SECTOR 14 TPX.DWG

11/5/2015 11:07 AM

File:
TBX.met

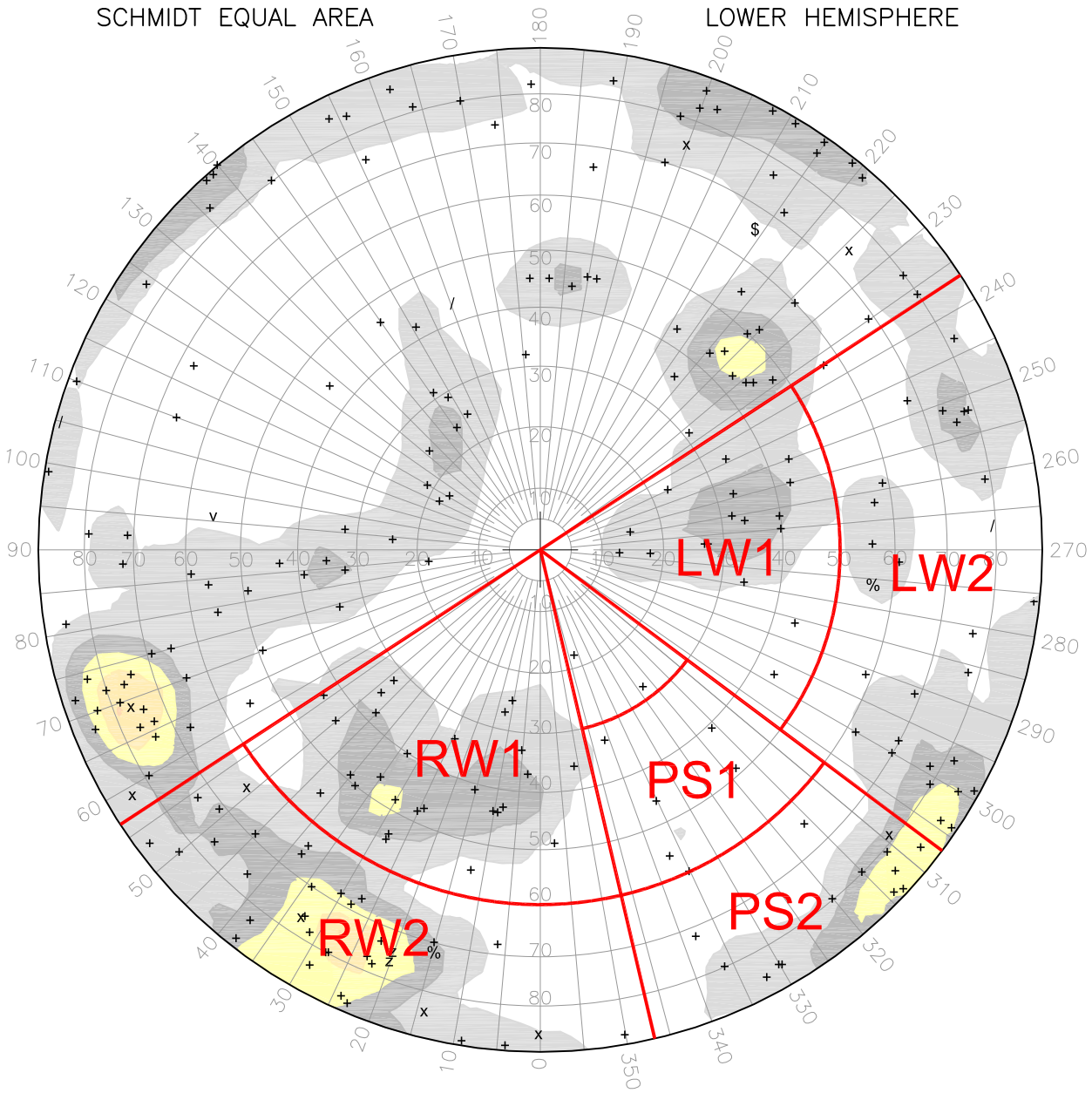


Figure 15F.
Backbreak Design Sets and Statistics
Sector 15, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 241

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	264.65	32.06	6.00	28.12	29.6%
LW2	277.26	73.70	4.04	9.70	50.0%
PS1	329.40	45.00	8.35	61.79	9.3%
PS2	321.27	80.07	3.71	14.56	27.8%
RW1	24.67	42.67	4.07	18.69	46.3%
RW2	28.86	77.08	2.88	15.06	57.4%

Acad File
\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 15F - SECTOR 15 TPX.DWG

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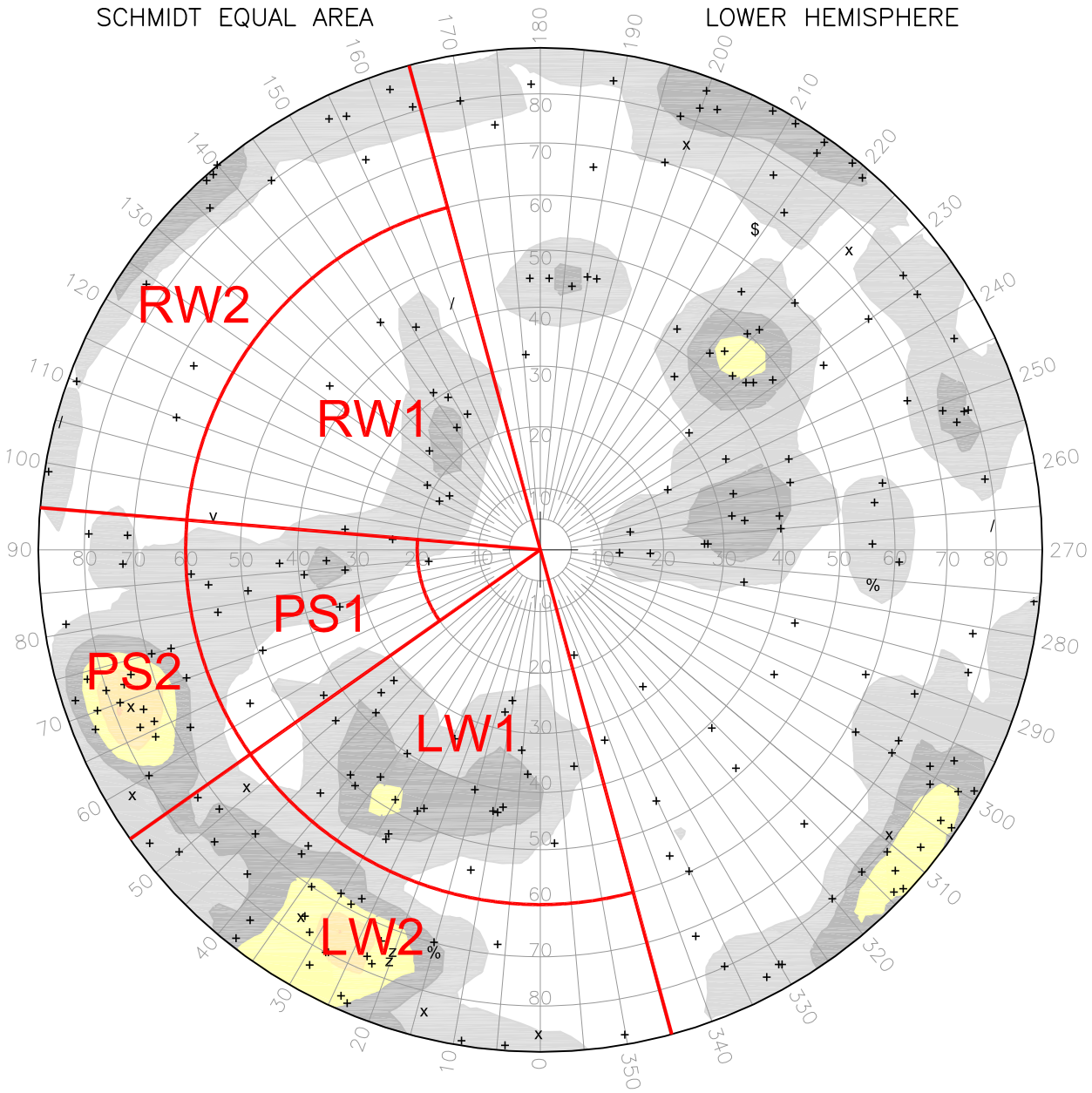


Figure 16F.
Backbreak Design Sets and Statistics
Sector 16, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 241

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	23.46	42.65	4.01	19.05	44.4%
LW2	28.86	77.08	2.88	15.06	57.4%
PS1	79.15	44.08	4.16	27.68	22.2%
PS2	72.13	76.26	2.54	18.63	37.0%
RW1	133.50	29.42	5.32	21.32	22.2%
RW2	136.67	82.40	3.83	14.80	27.8%

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\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 16F - SECTOR 16 TPX.DWG

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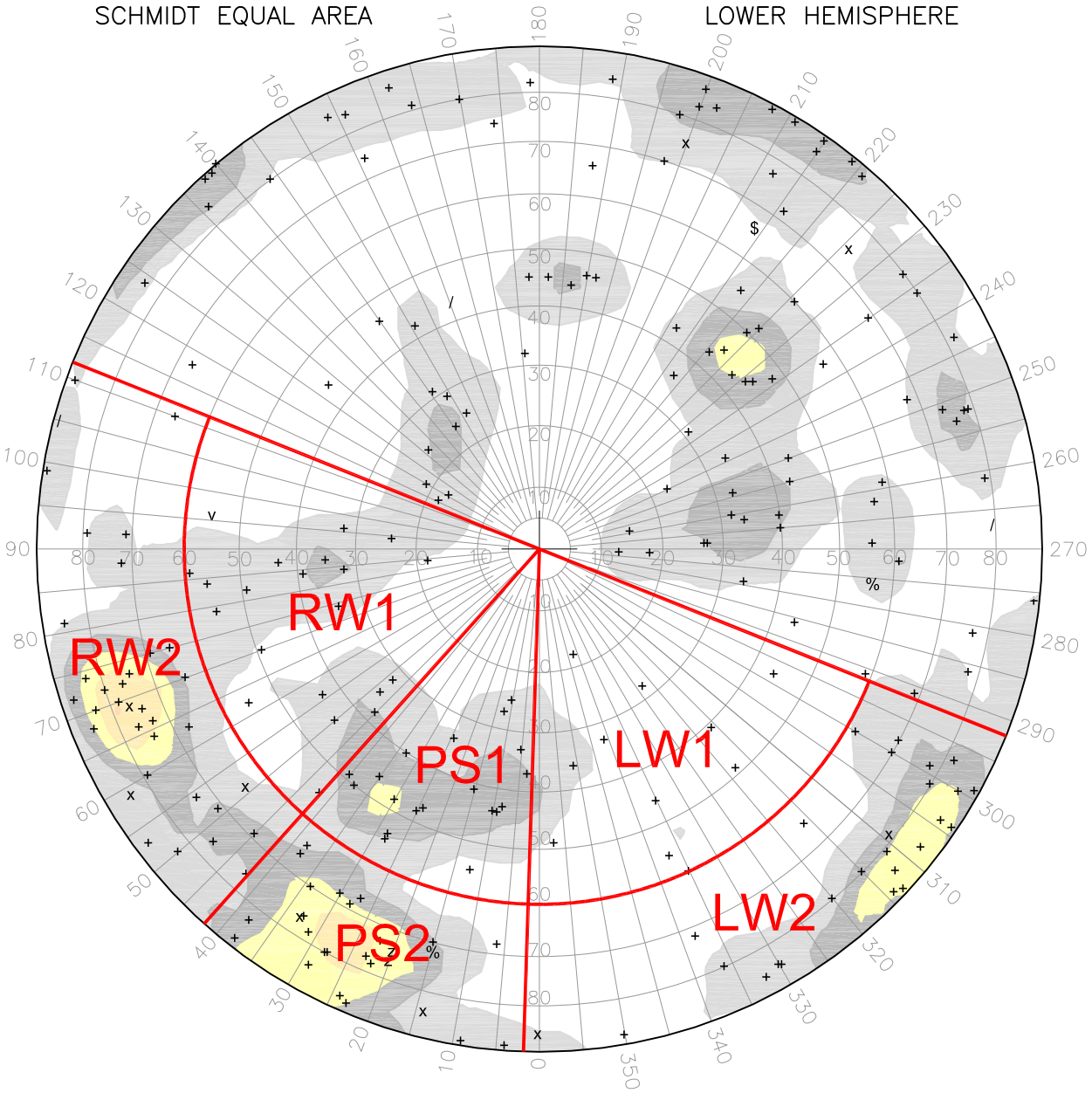


Figure 17F.
Backbreak Design Sets and Statistics
Sector 17, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 241

FISHER CONCENTRATION:

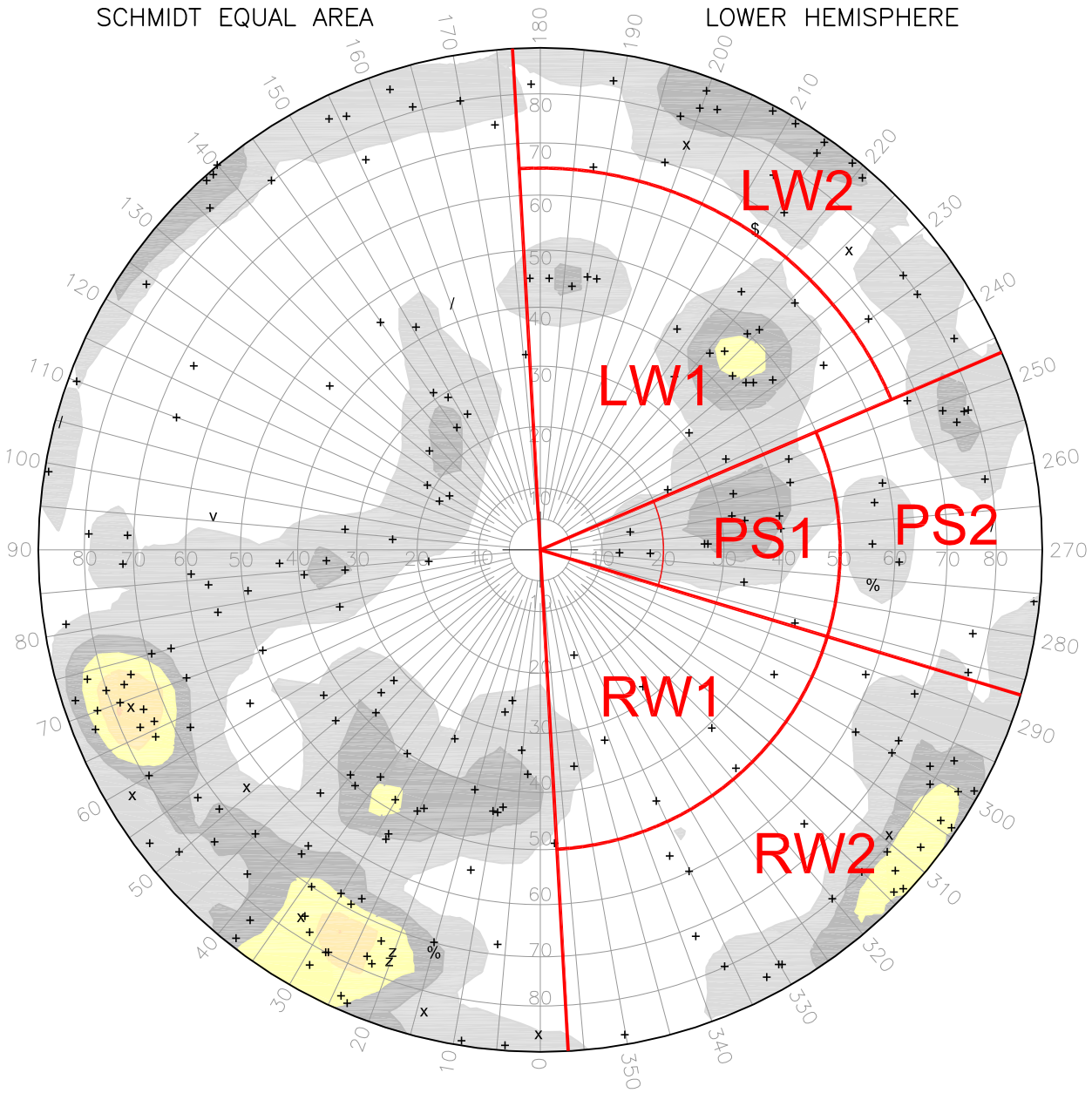
0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	331.80	40.00	7.39	41.47	18.5%
LW2	315.96	80.26	4.31	11.68	48.1%
PS1	20.47	43.16	4.18	22.74	33.3%
PS2	25.19	77.00	3.08	17.29	44.4%
RW1	72.10	41.35	4.34	22.66	33.3%
RW2	69.76	76.35	2.48	16.78	51.9%

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\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 17F - SECTOR 17 TPX.DWG

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CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 241

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	218.05	44.52	3.42	14.79	38.9%
LW2	211.09	80.73	2.49	14.15	37.0%
PS1	264.45	36.18	4.58	17.34	18.5%
PS2	263.23	71.62	3.76	11.73	24.1%
RW1	331.22	38.22	7.74	41.96	16.7%
RW2	313.45	78.10	4.15	12.32	50.0%

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\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 18F - SECTOR 18 TPX.DWG

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Figure 18F.
Backbreak Design Sets and Statistics
Sector 18, Pre-Cambrian

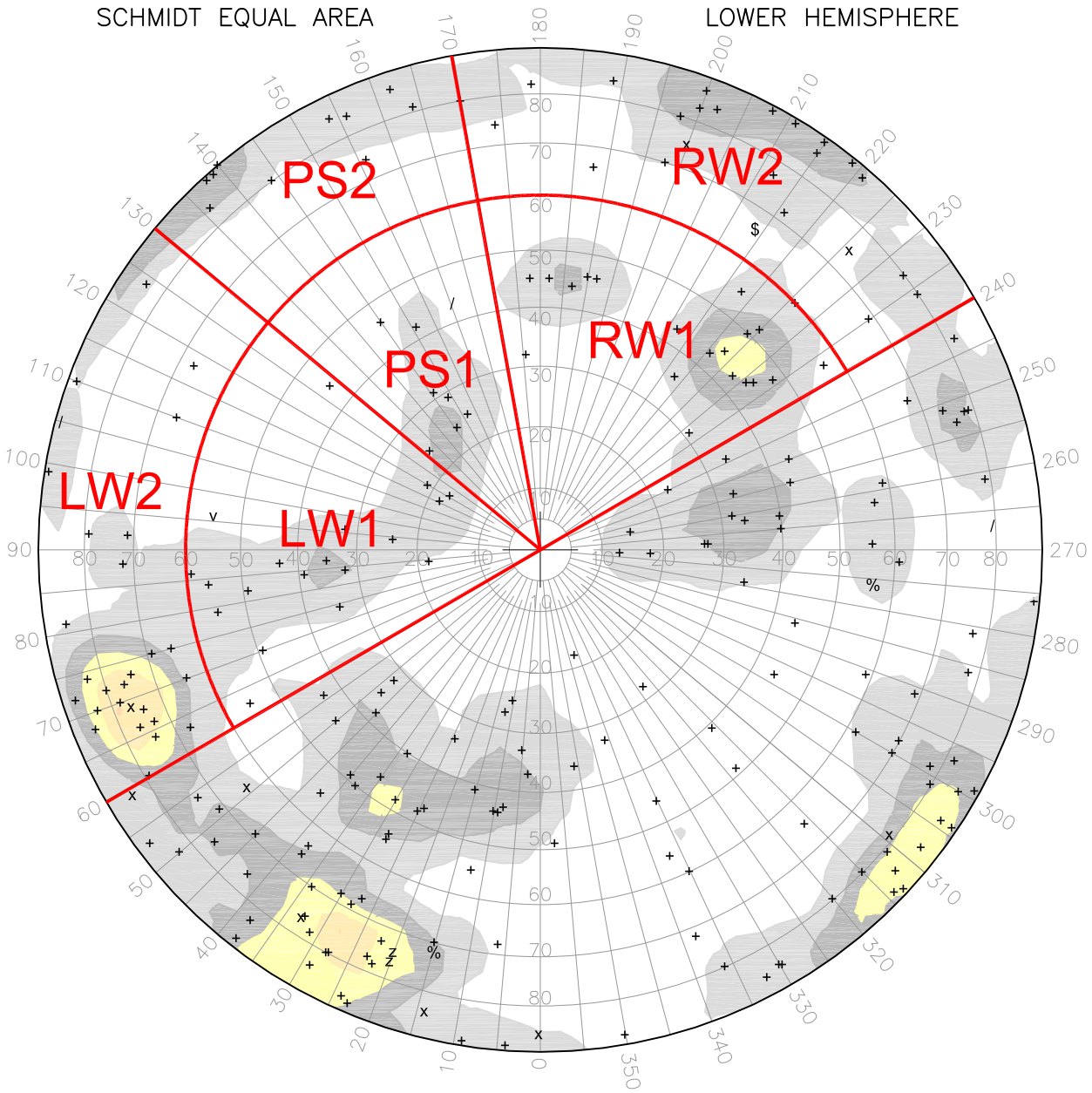


Figure 19F.
Backbreak Design Sets and Statistics
Sector 19, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 241

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	91.00	37.78	4.94	29.01	29.6%
LW2	80.04	76.44	2.82	18.51	42.6%
PS1	145.86	31.57	4.99	18.61	13.0%
PS2	148.90	84.20	3.78	13.18	18.5%
RW1	212.63	44.74	3.59	15.84	35.2%
RW2	207.12	79.50	2.26	14.44	37.0%

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\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 19F - SECTOR 19 TPX.DWG

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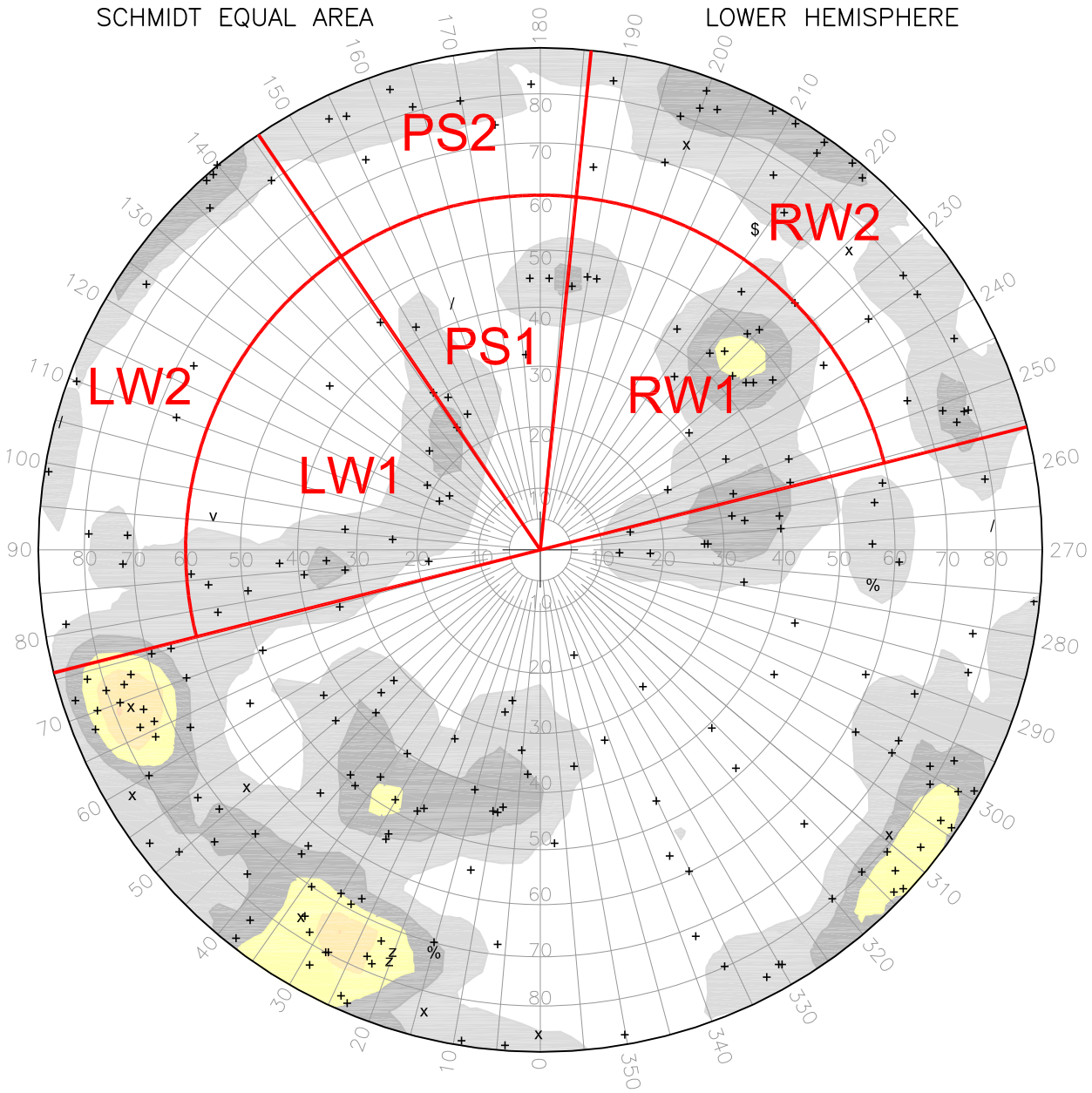


Figure 20F.
Backbreak Design Sets and Statistics
Sector 20, Pre-Cambrian

CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 241

FISHER CONCENTRATION:

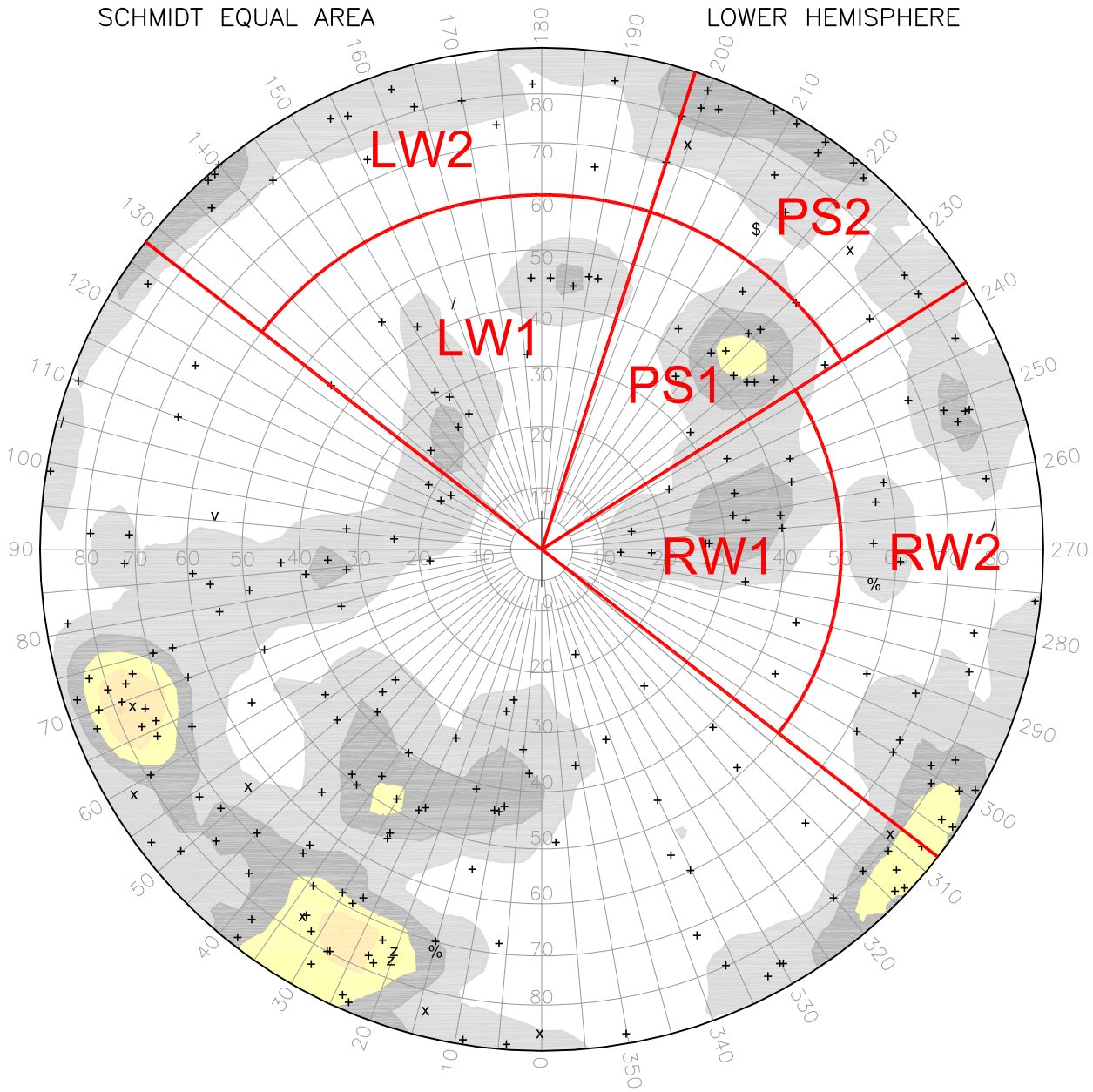
0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	105.32	35.11	4.46	24.05	33.3%
LW2	115.07	80.93	3.86	21.06	25.9%
PS1	164.67	36.33	5.53	18.54	11.1%
PS2	164.38	80.75	3.05	16.84	14.8%
RW1	226.29	43.10	3.61	16.76	37.0%
RW2	220.26	78.85	2.57	14.45	46.3%

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\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 20F - SECTOR 20 TPX.DWG

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CALL & NICHOLAS, INC.
TUCSON, ARIZONA USA

PLOT LEGEND

SET DATA:

+ = JOINT SET
o = FOLIATION SET

INDIVIDUAL STRUCTURES:

z = SINGLE JOINT
x = FAULT
$ = SHEAR ZONE
/ = DIKE
% = CONTACT
v = VEIN

NUMBER OF POINTS: 241

FISHER CONCENTRATION:

0.0% ~ 1.0%	4.0% ~ 5.0%
1.0% ~ 2.0%	5.0% ~ 6.0%
2.0% ~ 3.0%	6.0% ~ 7.0%
3.0% ~ 4.0%	

SET NO.	DDR	DIP	MEAN SPACING	MEAN LENGTH	PROB OF OCCUR
LW1	161.00	37.36	4.49	16.70	24.1%
LW2	163.82	81.06	3.22	17.46	29.6%
PS1	225.77	45.54	3.69	16.19	24.1%
PS2	216.18	80.71	2.17	9.87	29.6%
RW1	264.65	32.06	6.00	28.12	29.6%
RW2	279.89	74.78	4.08	10.02	50.0%

Acad File
\2015\NAU_STUDY\REPORT\APPENDIX F - BB DESIGN SETS\FIG 21F - SECTOR 21 TPX.DWG

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Figure 20F.
Backbreak Design Sets and Statistics
Sector 21, Pre-Cambrian

TECHNICAL MEMORANDUM

9400 Station Street
Suite 300
Lone Tree, CO 80124

T: 720.508.3300
F: 720.508.3339

To: **Chris Hanks**

From: **John W. Roberts, P.G., and Nick Rocco, Ph.D., P.E.**

Reviewed By: **Jay Janney-Moore, P.E.**

Project: **East Cresson Overburden Storage Area Stability Review/Update for Amendment No. 11 Permitting Submittal**

Project No.: 475.0106.005

Date: 30 November 2015

1.0 INTRODUCTION

Newmont Mining Corporation (Newmont) retained NewFields to review the stability of the East Cresson Overburden Storage Area (ECOSA) at the Cripple Creek & Victor Gold Mine (CC&V). The stability review was performed to assess if increasing the ultimate crest elevation resulted in unsafe conditions. The current development of ECOSA was permitted under the Cresson Project permit M-1980-244 Amendment 9. A modification to increase the ultimate crest height of ECOSA is being proposed under Amendment 11 to the Cresson Project permit. The ECOSA is currently permitted to an elevation of 10,565-feet above mean sea level (amsl). CC&V is planning to raise the crest of the facility to 10,950-feet amsl and NewFields has performed a geotechnical evaluation of the global stability of the ECOSA in consideration of the increased elevated storage capacity.

NewFields reviewed the original design report completed by Adrian Brown Consultants, Inc. (Adrian Brown, 2012) as well as the stability evaluation performed for the Squaw Gulch overburden storage area (AMEC, 2011). Using the available information, a stability analysis was completed for the ECOSA considering the proposed facility topography provided by CC&V and material properties previously used by Adrian Brown (2012) and NewFields (2014). A cursory update to assess the current seismic hazard at the site was also completed to verify the design seismic coefficients for the facility.



2.0 OVERBURDEN STORAGE AREA STABILITY EVALUATION

The stability analyses were performed using the computer program SLIDE 6 by Rocscience and completed for static and pseudo-static conditions. SLIDE is a two-dimensional slope stability program for evaluating circular or noncircular failure surfaces in soil or rock slopes using limit equilibrium methods. Spencer's procedure, which is applicable for all slope geometries and soil profiles, was utilized within the stability model and assumes all inter-slice forces are parallel and have the same inclination. Minimum acceptable factors of safety (FOS) for static and pseudo-static conditions are determined by the Colorado Division of Reclamation, Mining and Safety (DRMS) considering the facility is classified as a "critical structure" and there is a robust understanding of the strength characterization of the materials comprising the facility. Based on the recommendations of the DRMS, the minimum factors of safety are 1.3 and 1.15 for static and pseudo-static conditions, respectively. The previous ECOSA stability evaluation (Adrian Brown, 2012) considered a maximum crest elevation of 10,565-feet amsl, and resulted in a FOS of 1.66 and 1.16 for static and pseudo-static conditions, respectively.

2.1 Design Ground Motions

To assess the stability of slopes during seismic loadings, a pseudo-static approach was utilized in which the potential sliding mass is subjected to an additional, destabilizing horizontal force that represents the effects of earthquake motions and is related to the peak ground acceleration (PGA). The seismic force is the weight of the sliding mass multiplied by a horizontal pseudo-static earthquake coefficient (k_h).

The k_h is typically considered as a portion of the PGA because during an actual earthquake the acceleration within the potential sliding mass is cyclic and varies over the duration of the earthquake. Therefore, an average horizontal coefficient is assigned that is typically less than the PGA experienced at the base of the structure. Hynes-Griffin and Franklin (1984) discussed that use of one-half of the PGA for the horizontal pseudo-static earthquake coefficient will result in slope deformations that will be within tolerable limits.

For the current evaluation two different seismic coefficients were considered:

- The first value was based on the previous stability evaluation completed by Adrian Brown (2012) in which the PGA was identified as 0.14 gravity (g) for closure conditions, and the author chose to use the full PGA for k_h within the pseudo-static stability evaluation. This value is also consistent with AMEC (2011) and CC&V Amendment 9 (2008) for operating conditions.
- The second value was developed based on a review of publically available information regarding the seismic hazard at the ECOSA site using the United States Geologic Survey (USGS) interactive deaggregations tool. The updated PGA was listed as 0.11g for the 2475-



year-return seismic event, which NewFields considers a reasonable risk level for closure conditions and the existing understanding of the seismic region. The output graphic from the seismic hazard analysis identifying the PGA, mean earthquake magnitude, and mean rupture distance is presented in **Figure 1**. The current evaluation applied a one-third reduction to the PGA for k_h (0.073g), which we consider reasonable and conservative based on the recommendations of Hynes-Griffin and Franklin (1984). As a comparison, AMEC (2011) and CC&V Amendment 9 used a value of 0.08g for k_h for closure conditions.

2.2 Model Development

Stability was analyzed for three sections of the ECOSA, as shown in **Figure 2**. Generally, the stability sections were chosen to represent the most critical conditions where the native ground and facility slopes were steepest, and the cross sections are presented in **Figures 3, 4 and 5**.

Based on the topography provided by CC&V, some portions of the existing slopes are steeper than the permitted closure slopes (2.5H:1V). The steeper slopes will be regraded to 2.5H:1V as specified in the final design.

Section 1 was evaluated as it represents the greatest slope distance on the northeast side of the facility. Section 2 was evaluated to model the greatest length of natural ground slope underlying the northeast side of the facility. Section 3 was evaluated to analyze the steepest portion of the existing slope on the west side of the facility.

Subsurface stratigraphy of the foundation soils was developed using information referenced by Adrian Brown (2012). Neither an elevated phreatic surface within the facility or a natural ground water table near the ground surface was considered in the current evaluation and is consistent with the previous stability evaluations and our understanding of the facility.

2.3 Material Properties

Material properties used for the analysis were taken from previous stability evaluations at CC&V (Adrian Brown, 2012; NewFields, 2014). The properties for each material type are described below and listed in **Table 2.1**.

Table 2.1
Summary of Material Properties

Material	Moist Unit Weight (lb/ft^3)	Cohesion (lb/ft^2)	ϕ (deg)
Overburden	115	0	39
Colluvium	120	0	29
Bedrock	145	5000	45



- Overburden: Material properties are consistent with those utilized by Adrian Brown (2012) and NewFields (2014), and it is NewFields' opinion that the referenced strength is reasonable for the material.
- Colluvium: Strength parameters for the colluvial foundation was taken from Adrian Brown (2012). The friction angle (ϕ) of 29 degrees were developed from an empirical relationship between shear strength, liquid limit and clay fraction of the material. In comparison, AMEC (2011) characterized the strength of the near surface sediments with a 32 degree friction angle. Based on our understanding of the material, the ϕ for this material is reasonable and conservative.
- Bedrock: The unit weight for bedrock was taken from Adrian Brown (2012). The ϕ used was not provided in the original analysis, although, the descriptor "unbreakable" was given (Adrian Brown, 2012). The ϕ and cohesion values of 45 degrees and 5,000, respectively, were taken from previous work completed at the CC&V Squaw Gulch Valley Leach Facility by AMEC (2011).

2.4 Stability Evaluation Results

The stability analyses resulted in acceptable minimum FOS values for both static and pseudo-static conditions, as show in **Table 2.2**. The pseudo-static analyses using the PGA from the 2475-year return (k_h = 0.073) also resulted in acceptable minimum FOS values for all sections analyzed. The output graphics from the stability models are included as **Attachment A**.

The Section 3 pseudo-static analysis, using the larger horizontal pseudo-static earthquake coefficient (k_h = 0.14), resulted in a FOS of 1.0, which is at the limit of equilibrium and does not meet the prescribed requirements of the DRMS. The primary factor influencing the calculated FOS is that this section of the storage area is steeper than the permitted closure slopes, which will be 2.5H:1V. Currently this section of the slope is approximately 1.6H:1V, and naturally steeper slopes have a lower factor of safety.

NewFields believes a PGA of 0.14g is highly conservative based on the results of the updated seismic hazard evaluation for the site (**Figure 1**), utilization of the full PGA within a pseudo-static stability evaluation compounds the conservatism, and ultimately the pseudo-static evaluations using a lower acceleration are reasonable for closure conditions and the current understanding of seismicity in the region. In addition, upon closure the slopes will be regraded to 2.5H:1V resulting in more stable slopes for long-term, closure conditions.

Table 2.2
Global Failure Surface Factors of Safety

Failure Section	Failure Mode	Static	Pseudo-Static (k_h = 0.14)[1]	Pseudo-Static (k_h = 0.073)[2]
Section 1	Global	1.8	1.2	1.5
Section 2	Global	1.8	1.3	1.5
Section 3	Global	1.4	1.0	1.2

Notes: [1] Horizontal seismic coefficient consistent with Adrian Brown (2012) stability evaluation
[2] Horizontal seismic coefficient based on the updated SHA performed as part of the current evaluation

3.0 SUMMARY

Newmont's CC&V mine has planned to increase the storage capacity of the ECOSA by raising the permitted crest elevation from 10,565 to 10,950-feet amsl. NewFields completed a stability analysis for static and pseudo-static conditions to evaluate the stability of the revised configuration for global failures under closure conditions. Based on the results of the stability evaluation, the larger ECOSA will remain stable under both static and dynamic conditions for operating and closure conditions, and all calculated factors of safety achieve the prescribed requirements of the DRMS

If you have any questions or require additional information, please contact the undersigned.

Sincerely,

NewFields Mining Design & Technical Services

John W. Roberts, P.G.
Project Geologist

Nicholas T. Rocco, Ph.D., P.E.
Project Manager

Reviewed by:

Jay Janney-Moore, P.E.
Project Manager

JWR/NTR/JNM

Attachments: Figure 1-5; Attachment A

Addressee: (via e-mail)

P:\Projects\0106.005 CCV Slope Stability & Water Balance\J-REPORTS\CCV_Stability_TechnicalMemo_Rev1.docx

REFEREENCES

Adrian Brown (2012). "Cresson Project, East Cresson Overburden Storage Area Evaluation," February 24th.

AMEC (2011). "Squaw Gulch Overburden Storage Area Including Mill Platform Stability Evaluation," January 5, 2011.

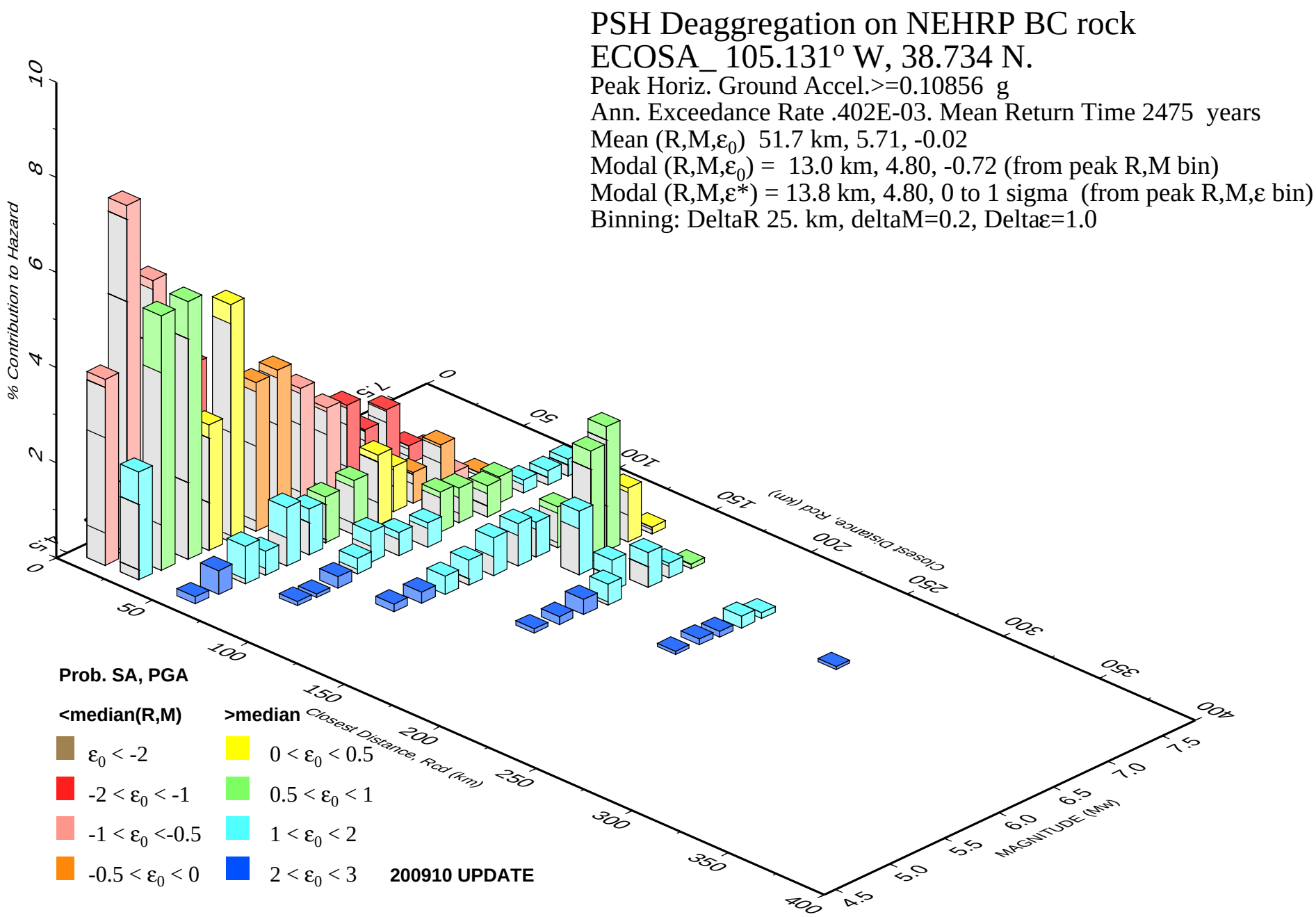
Cripple Creek & Victor Gold Mining Company. (2008). "Amendment 9 to Office of Mined Land Reclamation Permit M-1980-244".

Hynes, M.E., Franklin, A.G. (1984). "Rationalizing the Seismic Coefficient Method," Department of the Army, U.S. Army Corps of Engineers, Miscellaneous Paper GL-84-13.

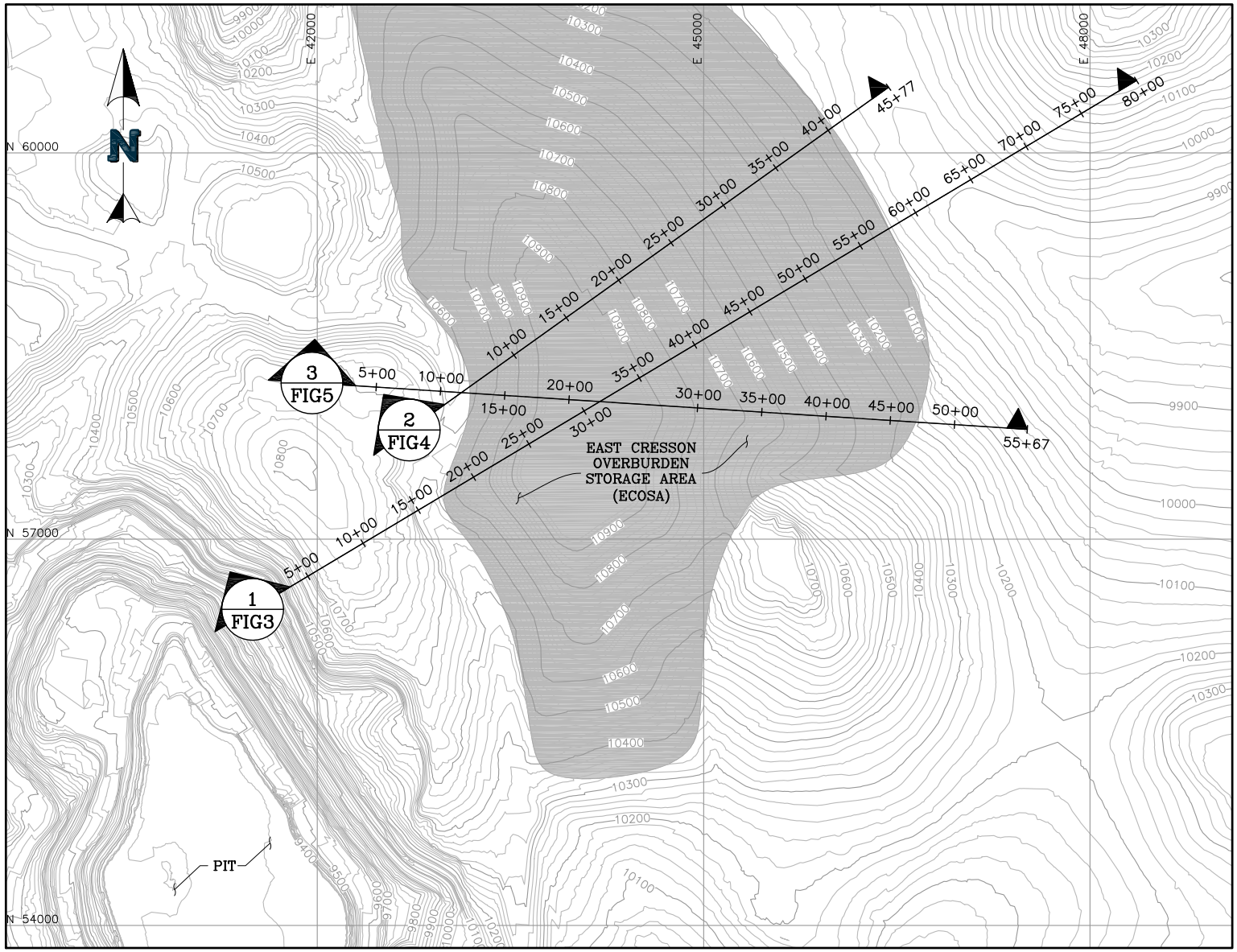
NewFields (2014). "Stability Re-evaluation: Squaw Gulch Valley Leach Facility," Technical Memorandum, January 28th.

FIGURES

FIGURE 1



GMT 2015 Nov 10 21:49:15 **Distance (R), magnitude (M), epsilon (E0,E) deaggregation for a site on rock with average vs= 760. m/s top 30 m. USGS CGHT PSHA2008 UPDATE Bins with lt 0.05% contrib. omitted**



LEGEND:

EXISTING GROUND CONTOURS

APPROXIMATE ECOSA FOOTPRINT

0 600 1200 FEET

TOPOGRAPHIC INFORMATION WAS CREATED FROM DATA PROVIDED BY CRIPPLE CREEK AND VICTOR GOLD MINING COMPANY RECEIVED ON JULY 30TH, 2015.

NewFields

CLIENT CRIPPLE CREEK AND VICTOR GOLD MINING COMPANY

PROJECT ECOSA SLOPE STABILITY REVIEW/UPDATE

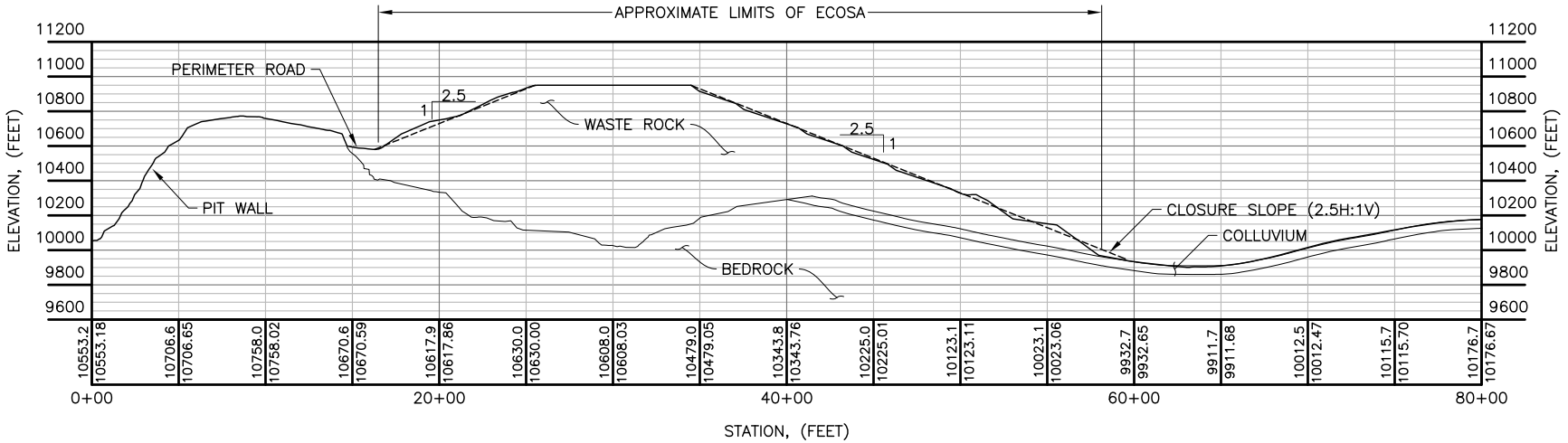
TITLE EAST CRESSON OVERBURDEN STORAGE AREA

FILENAME 0106.005.002F

FIGURE NO. 2

REVISION A

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1 FIG2 EAST CRESSON OVERBURDEN STORAGE AREA SECTION 1

0 500 1000 FEET HORIZONTAL

0 500 1000 FEET VERTICAL

NO EXAGGERATION

NewFields

CLIENT CRIPPLE CREEK AND VICTOR GOLD MINING COMPANY

PROJECT ECOSA SLOPE STABILITY REVIEW/UPDATE

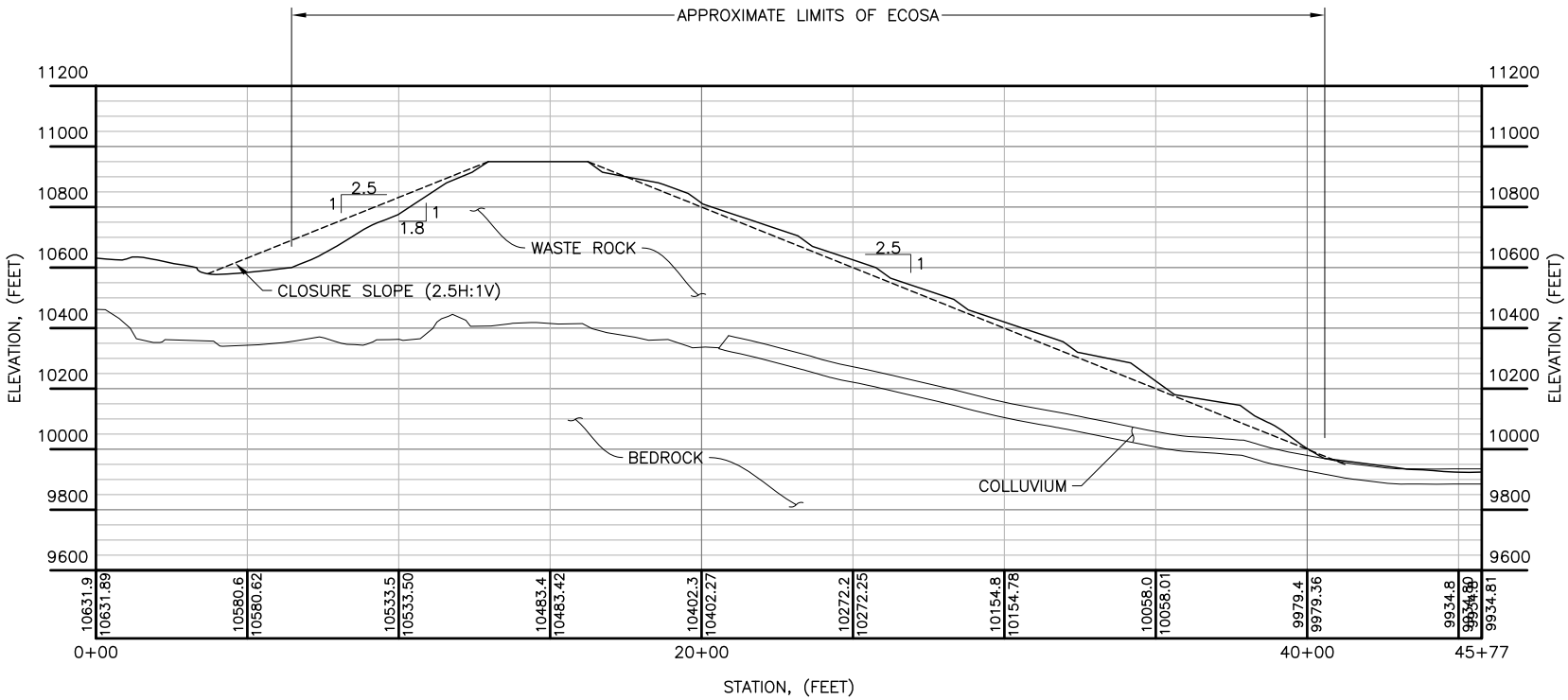
TITLE EAST CRESSON OVERBURDEN STORAGE AREA SECTION 1

FILENAME 0106.005.002F

FIGURE NO. 3

REVISION A

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2 / FIG2 EAST CRESSON OVERBURDEN STORAGE AREA SECTION 2

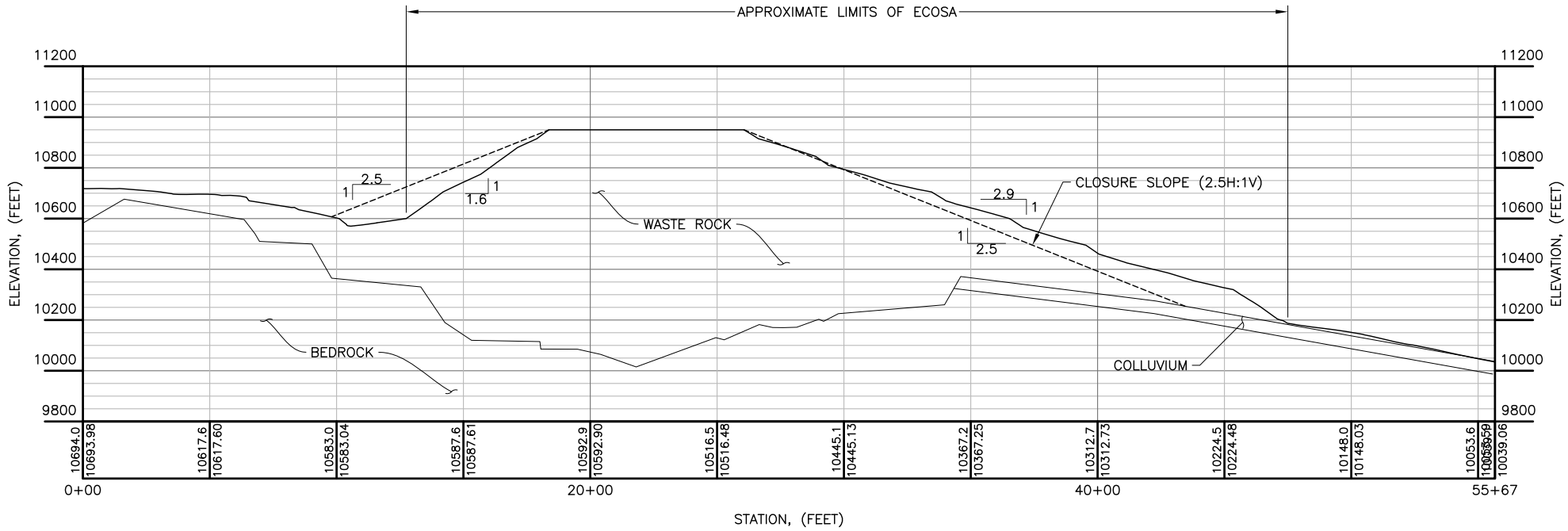
0 300 600 FEET
HORIZONTAL

0 300 600 FEET
VERTICAL

NO EXAGGERATION

NewFields	CLIENT CRIPPLE CREEK AND VICTOR GOLD MINING COMPANY	
PROJECT ECOSA SLOPE STABILITY REVIEW/UPDATE		
TITLE EAST CRESSON OVERBURDEN STORAGE AREA SECTION 2	FILENAME 0106.005.002F	
	FIGURE NO. 4	REVISION A

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3
FIG2
EAST CRESSON OVERBURDEN STORAGE AREA SECTION 3

0 300 600 FEET
HORIZONTAL

0 300 600 FEET
VERTICAL

NO EXAGGERATION

NewFields

CLIENT CRIPPLE CREEK AND VICTOR GOLD MINING COMPANY

PROJECT ECOSA SLOPE STABILITY REVIEW/UPDATE

TITLE EAST CRESSON OVERBURDEN STORAGE AREA SECTION 3

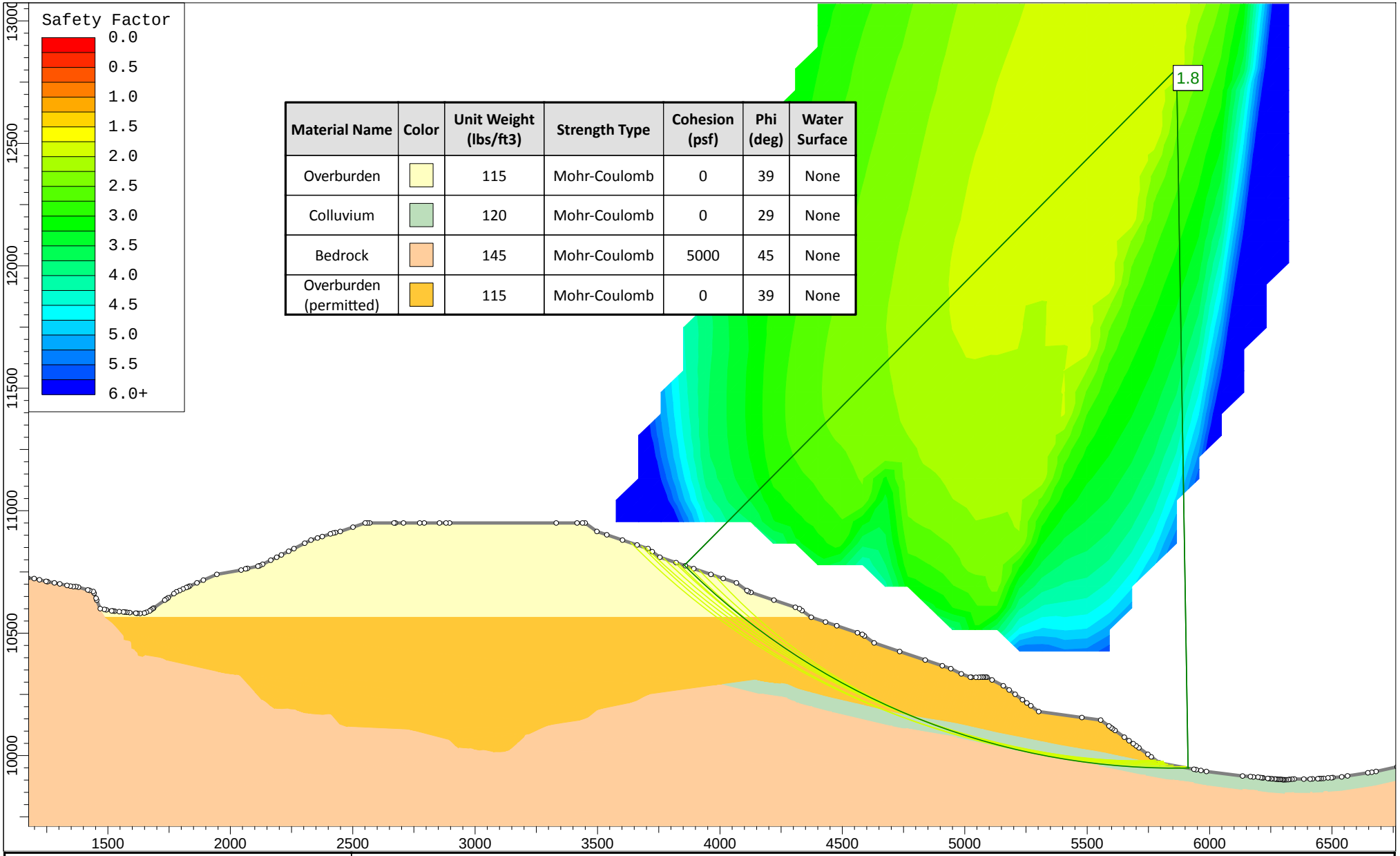
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FIGURE NO. 5

REVISION A

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ATTACHMENT A
Stability Output Graphics

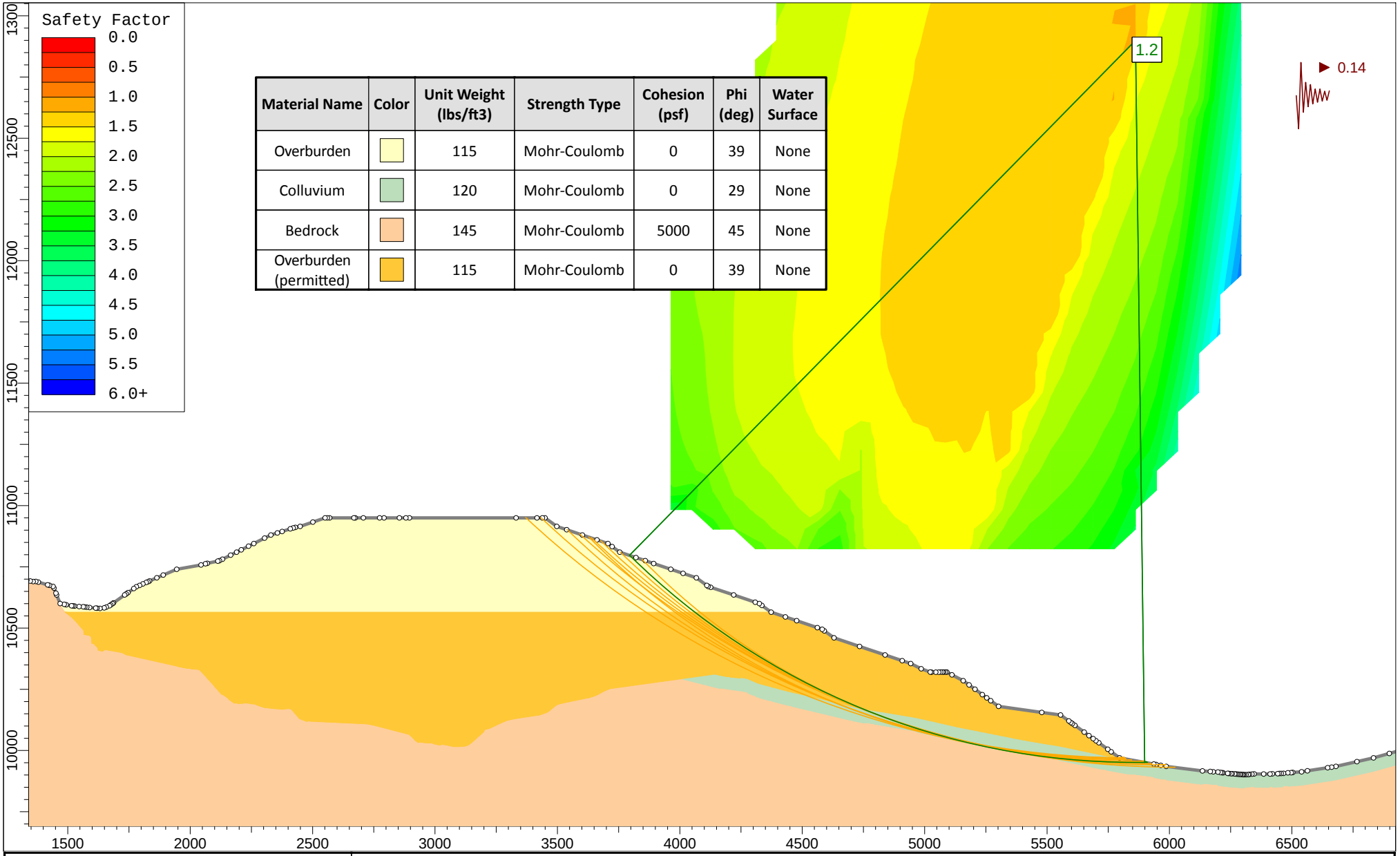


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Overburden		115	Mohr-Coulomb	0	39	None
Colluvium		120	Mohr-Coulomb	0	29	None
Bedrock		145	Mohr-Coulomb	5000	45	None
Overburden (permitted)		115	Mohr-Coulomb	0	39	None

NewFields

SLIDEINTERPRET 6.036

Project	East Cresson Overburden Storage Area				
Analysis Description	Section 1 - Static Stability				
Drawn By	JWR	Scale	1:6500	Company	CC&V
Date	10/27/2015, 9:55:10 AM			File Name	Section 1 - Static.slim

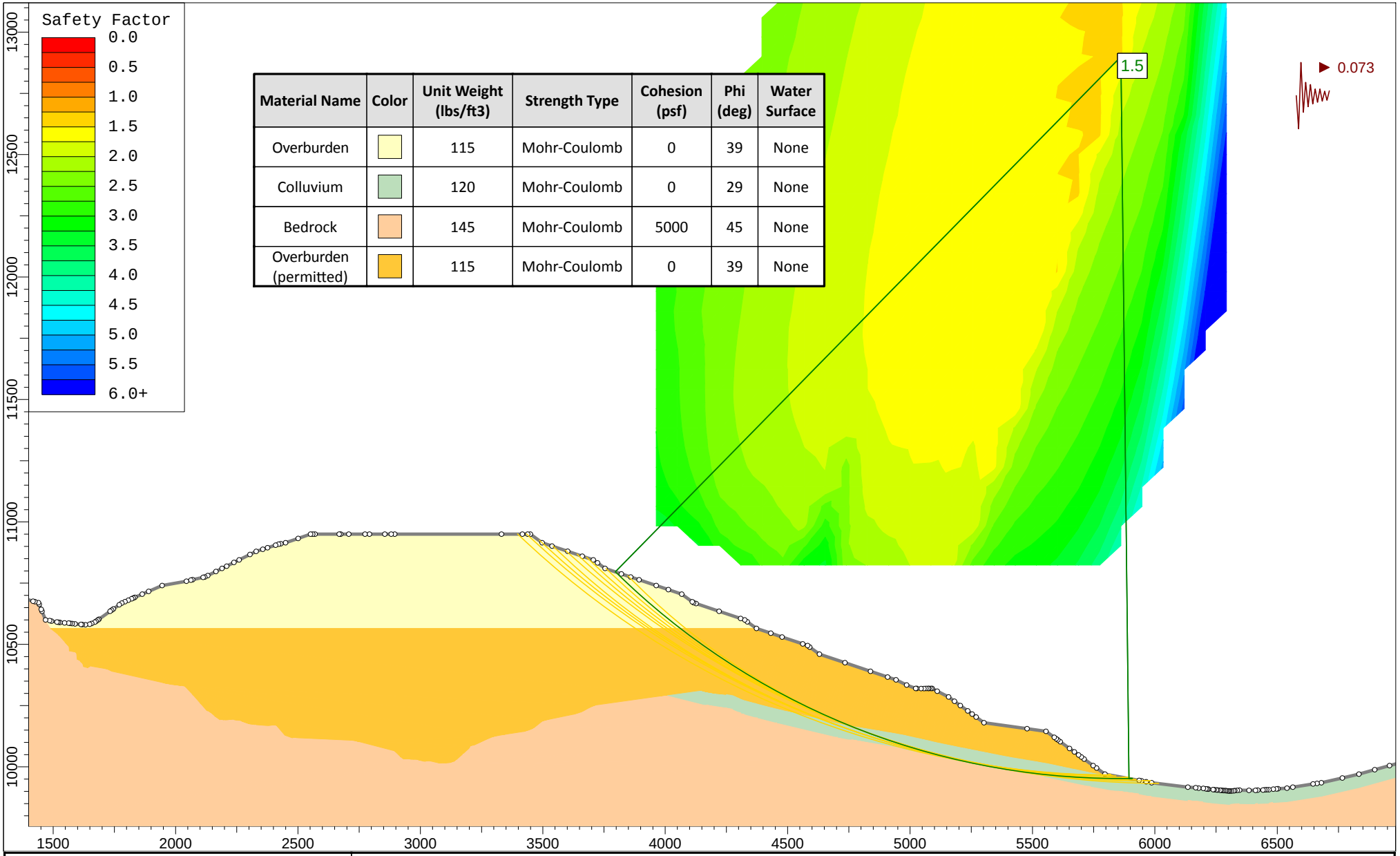


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
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Overburden (permitted)		115	Mohr-Coulomb	0	39	None

NewFields

SLIDEINTERPRET 6.036

Project	East Cresson Overburden Storage Area			
Analysis Description	Section 1 - Pseudo-Static Stability			
Drawn By	JWR	*Scale*	1:6500	*Company* CC&V
Date	10/27/2015, 9:55:10 AM			*File Name* Section 1 - Pseudo-Static.slim

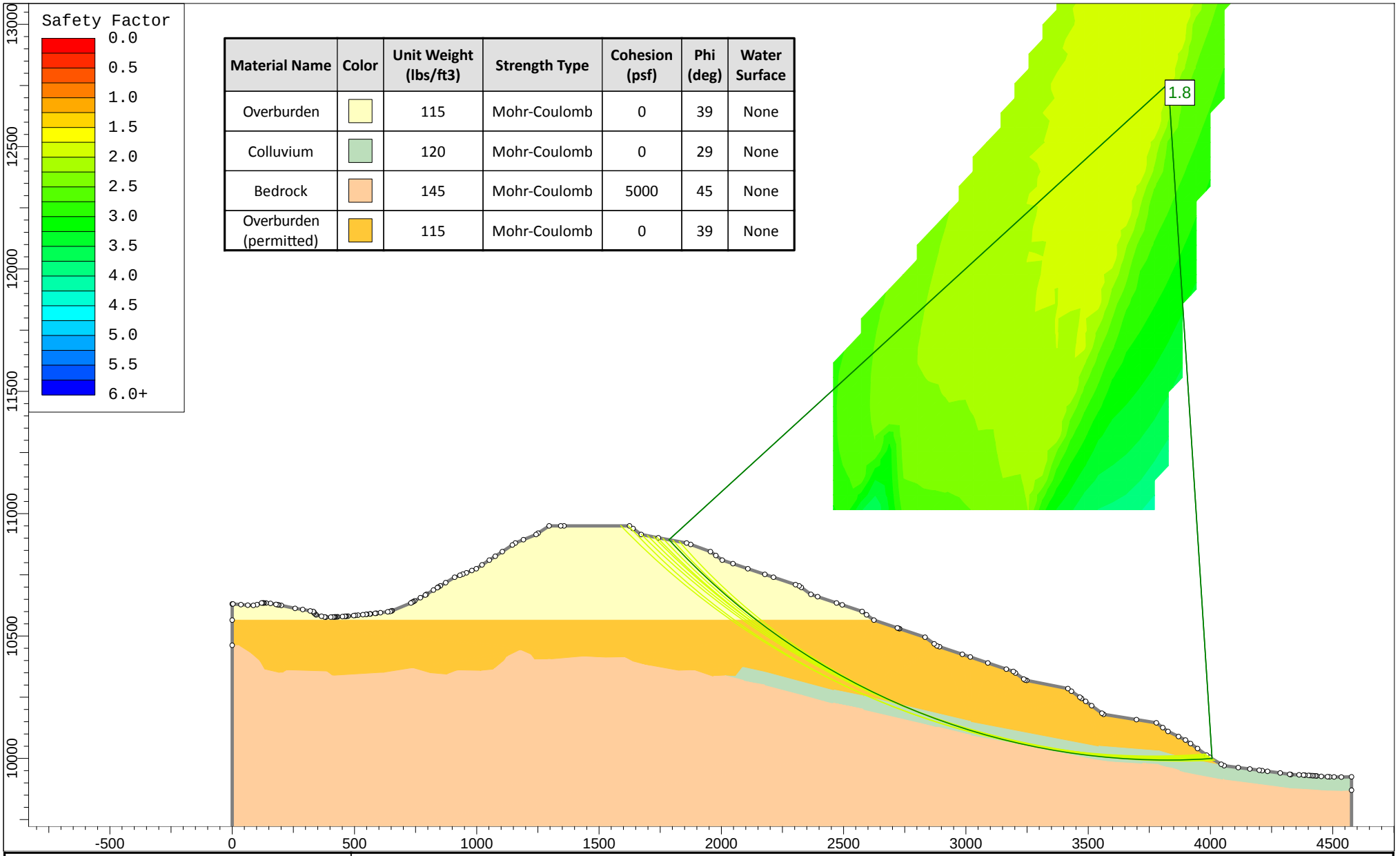


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Overburden (permitted)		115	Mohr-Coulomb	0	39	None

NewFields

SLIDEINTERPRET 6.036

Project	East Cresson Overburden Storage Area		
Analysis Description	Section 1 - Pseudo-Static Stability - 2475yr		
Drawn By	JWR	*Scale* 1:6500	*Company* CC&V
Date	10/27/2015, 9:55:10 AM		*File Name* Section 1 - Pseudo-Static 2475yr.slim

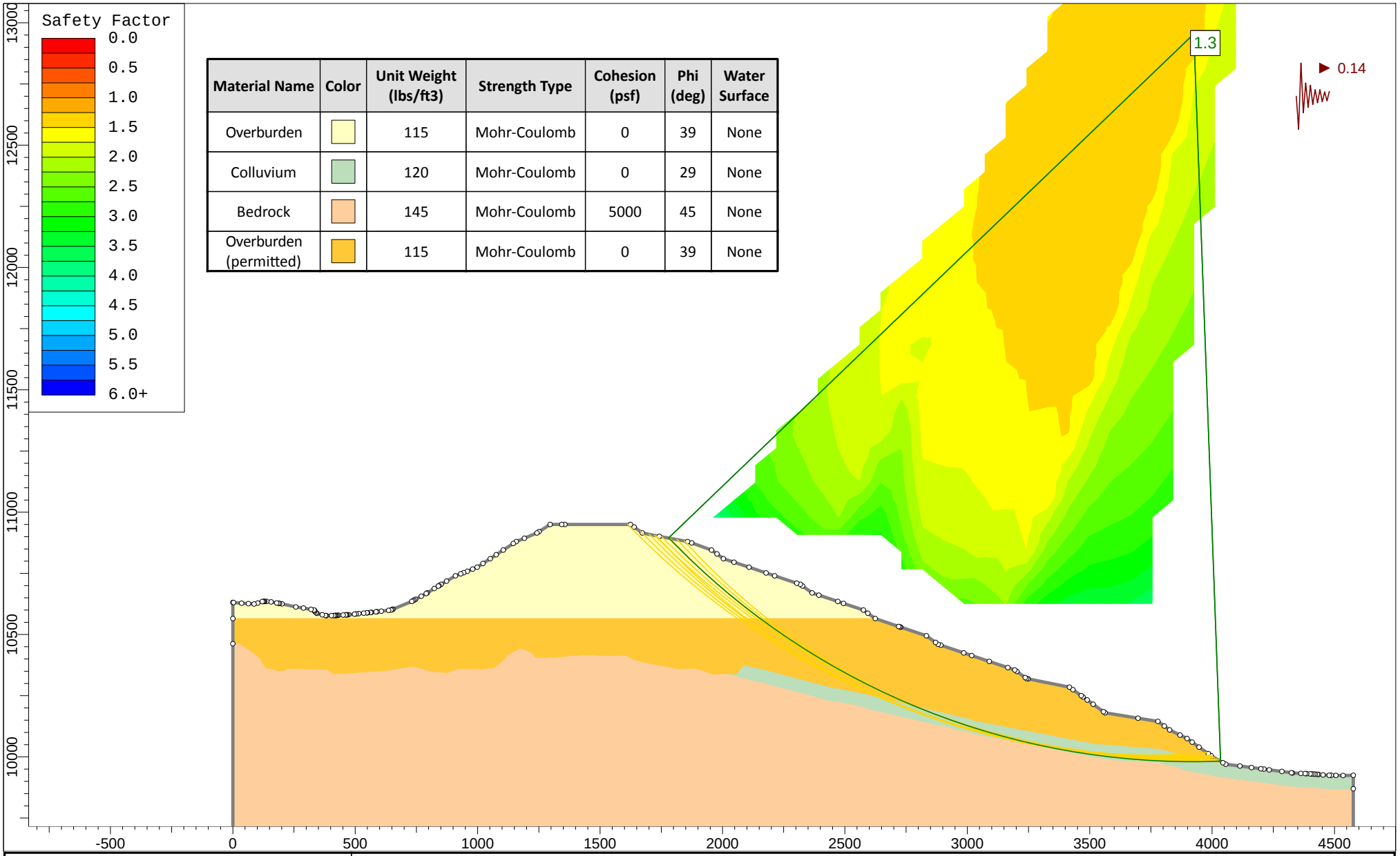


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Overburden		115	Mohr-Coulomb	0	39	None
Colluvium		120	Mohr-Coulomb	0	29	None
Bedrock		145	Mohr-Coulomb	5000	45	None
Overburden (permitted)		115	Mohr-Coulomb	0	39	None

NewFields

Project	East Cresson Overburden Storage Area			
Analysis Description	Section 2 - Static Stability			
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Date	10/27/2015, 12:03:40 PM			File Name Section 2 - Static.slim

SLIDEINTERPRET 6.036

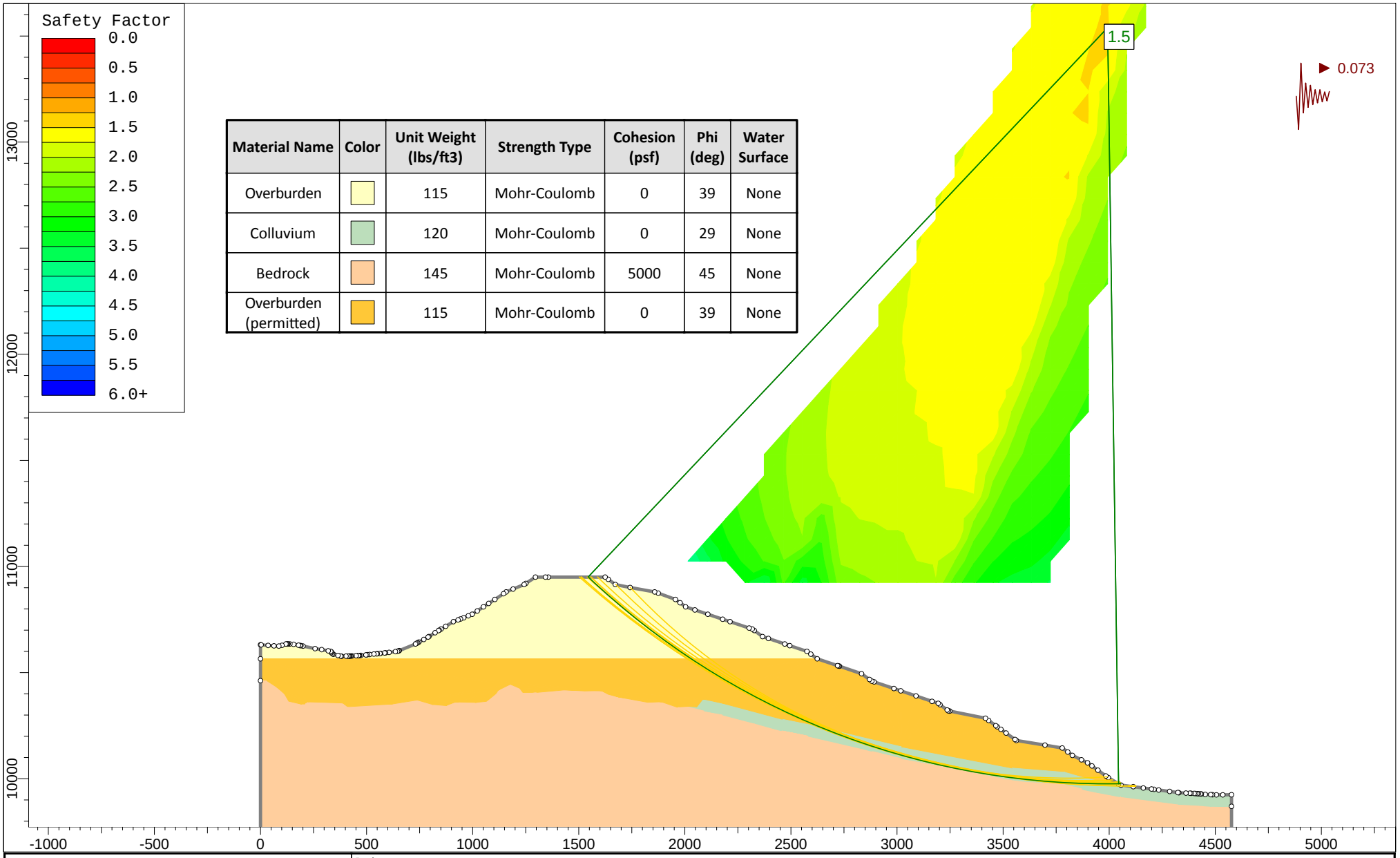


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NewFields

Project	East Cresson Overburden Storage Area			
Analysis Description	Section 2 - Pseudo-Static Stability			
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SLIDEINTERPRET 6.036

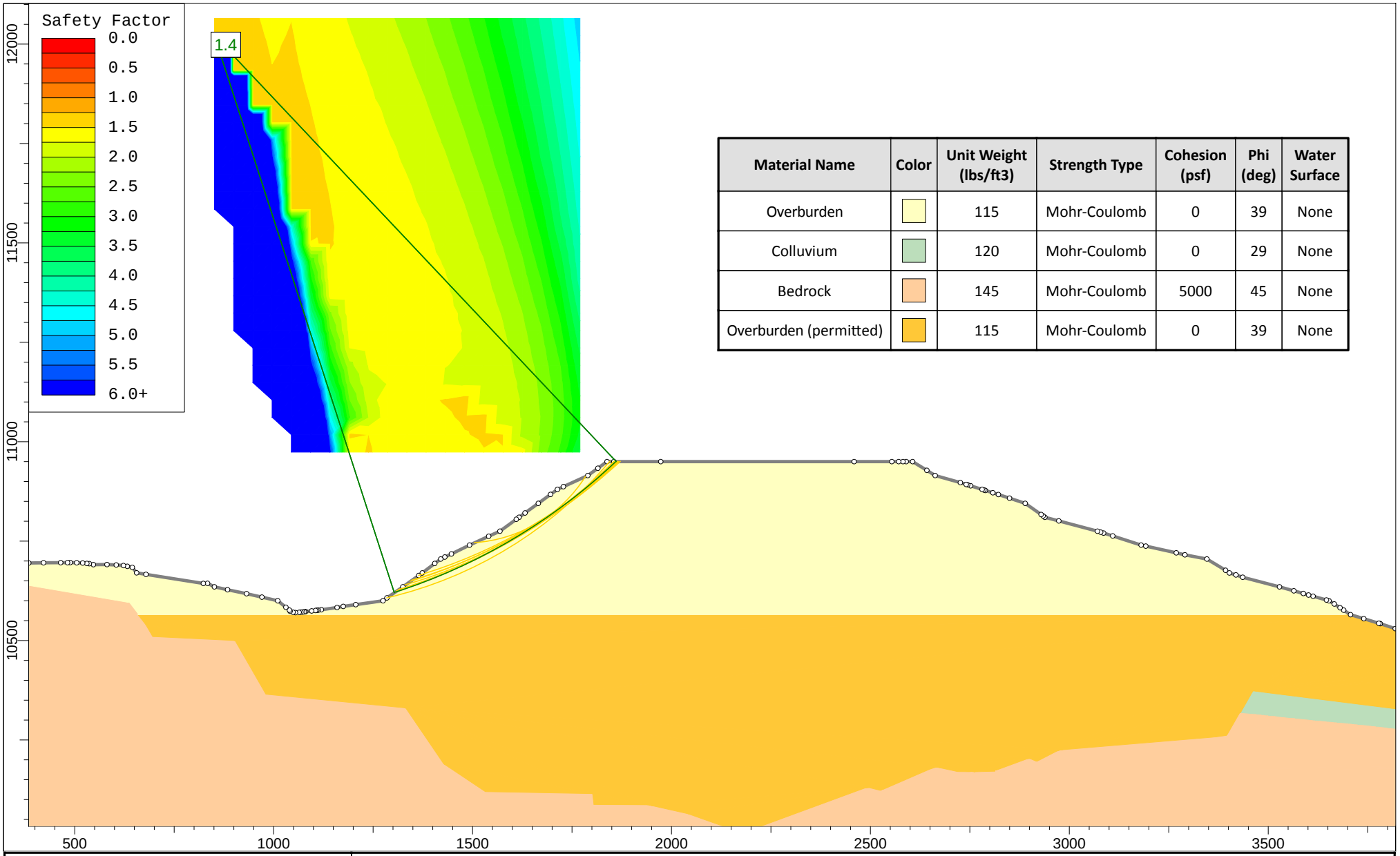


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NewFields

SLIDEINTERPRET 6.036

Project	East Cresson Overburden Storage Area		
Analysis Description	Section 2 - Pseudo-Static Stability - 2475yr		
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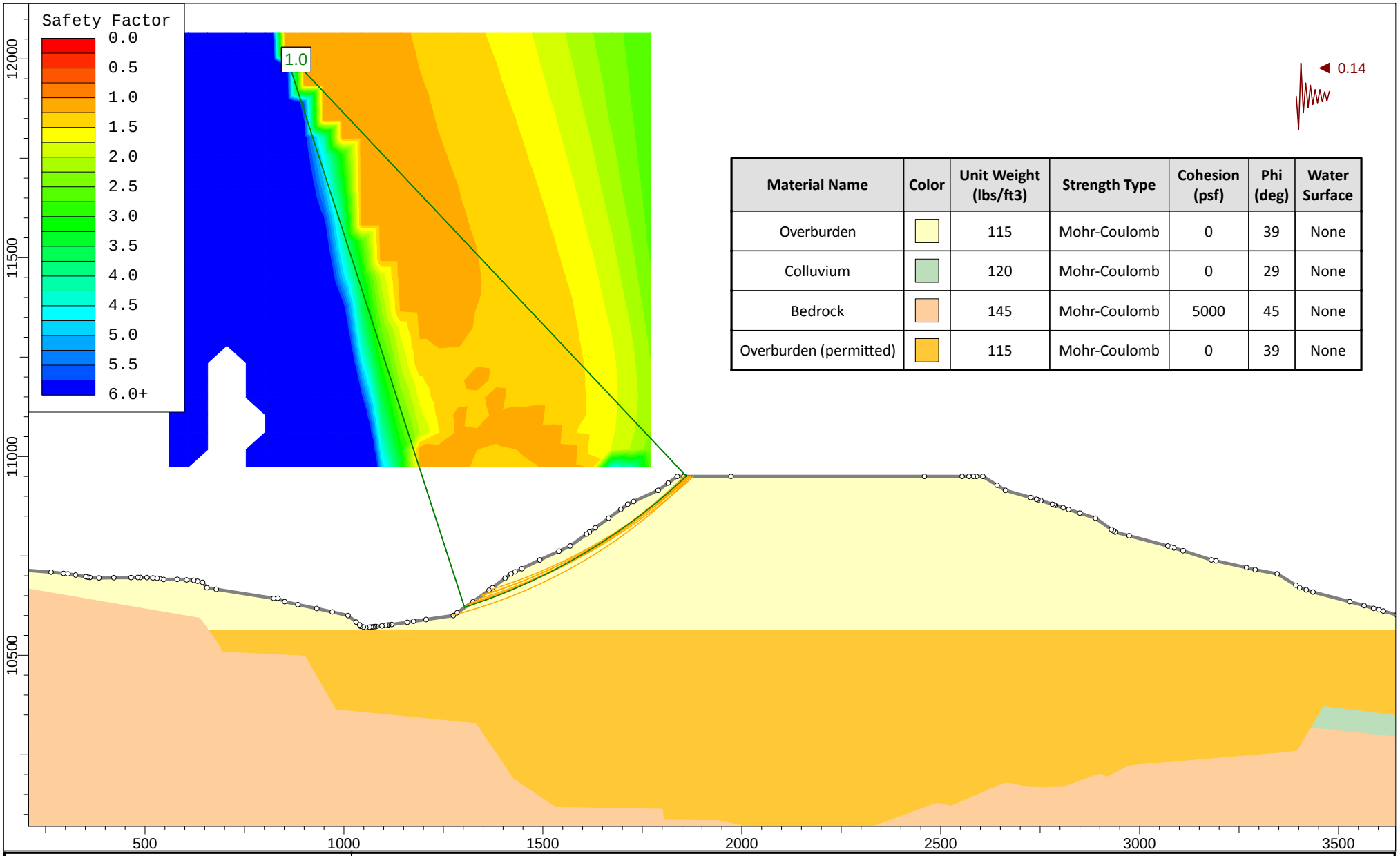


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NewFields

SLIDEINTERPRET 6.036

Project	East Cresson Overburden Storage Area			
Analysis Description	Section 3 - Static Stability			
Drawn By	JWR	Scale	1:4000	Company CC&V
Date	11/12/2015, 9:05:44 AM			File Name Section 3 - Static Stability.slim

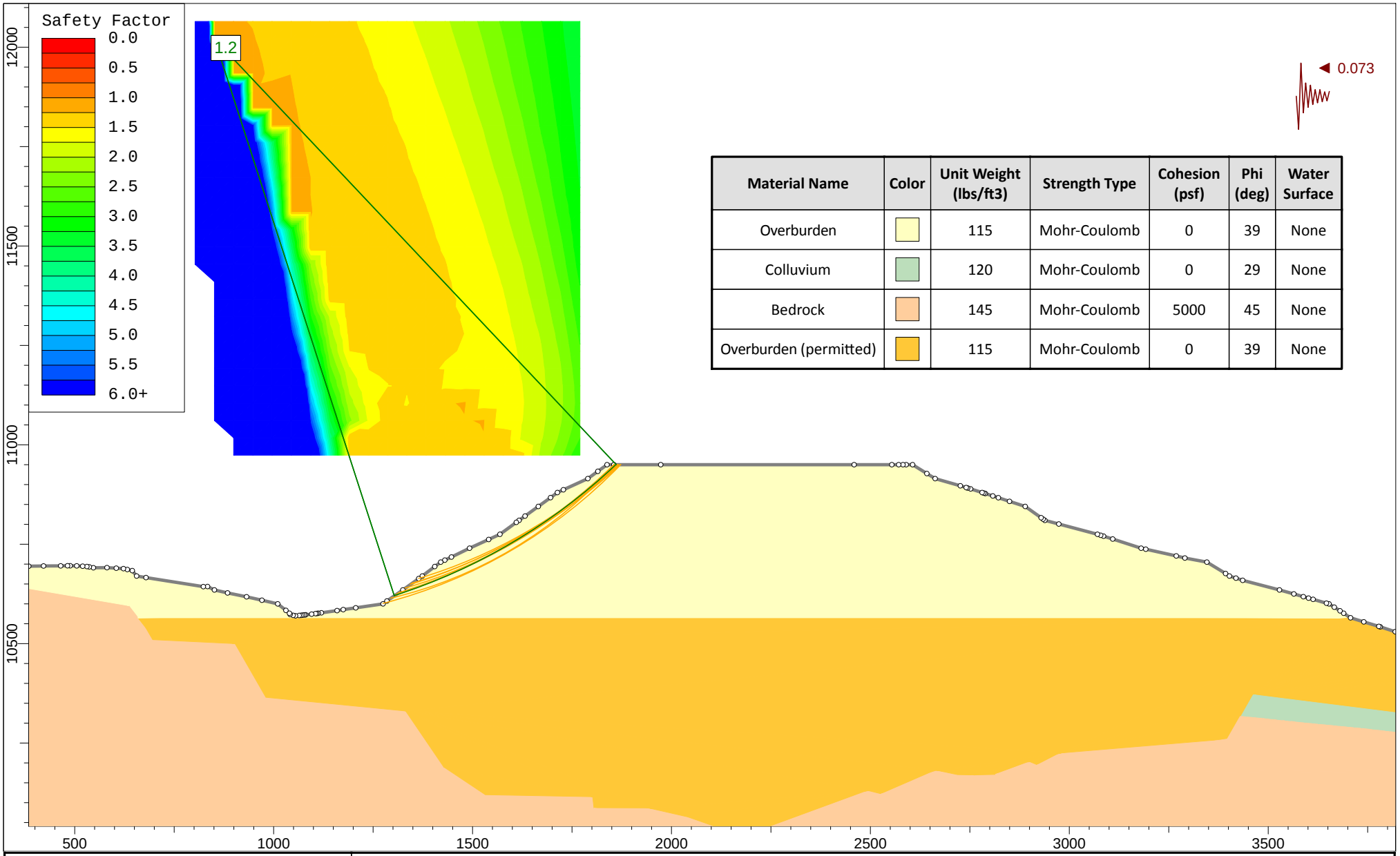


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
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NewFields

SLIDEINTERPRET 6.036

Project	East Cresson Overburden Storage Area			
Analysis Description	Section 3 - Pseudo-Static Stability			
Drawn By	JWR	Scale	1:4000	Company CC&V
Date	11/12/2015, 9:05:44 AM			File Name Section 3 - Pseudo-Static Stability.slim



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Overburden		115	Mohr-Coulomb	0	39	None
Colluvium		120	Mohr-Coulomb	0	29	None
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NewFields

SLIDEINTERPRET 6.036

Project	East Cresson Overburden Storage Area		
Analysis Description	Section 3 - Pseudo-Static Stability - 2475yr		
Drawn By	JWR	Scale 1:4000	Company CC&V
Date	11/12/2015, 9:05:44 AM		File Name Section 3 - Pseudo-Static Stability 2475yr.slim

Ecological Resource Consultants, Inc.

35715 US Hwy. 40, Suite D204 ~ Evergreen, CO ~ 80439 ~ (303) 679-4820

Technical Memorandum



Date: November 11, 2015

To: Jay Moore, NewFields

From: Ryan Hummel/Troy Thompson, ERC

Re: Cripple Creek & Victor Water Balance

Introduction

Ecological Resource Consultants, Inc. (ERC) has completed water balance analyses for the Squaw Valley and Arequa Gulch Valley Leach Facilities (VLF) at the Cripple Creek & Victor (CCV) Gold Mine at the request of NewFields. The two sites are part of the overall mine operations located in Teller County, Colorado. The purpose of the analyses was to predict potential monthly fluctuations in solution within the systems to ensure that adequate storage capacity is maintained throughout planned operations. The water balance model was developed using GoldSim version 9.60 software. This software facilitates stochastic analysis and allowed ERC to evaluate a range of potential outcomes when evaluating the adequacy of the system.

Water Balance Components

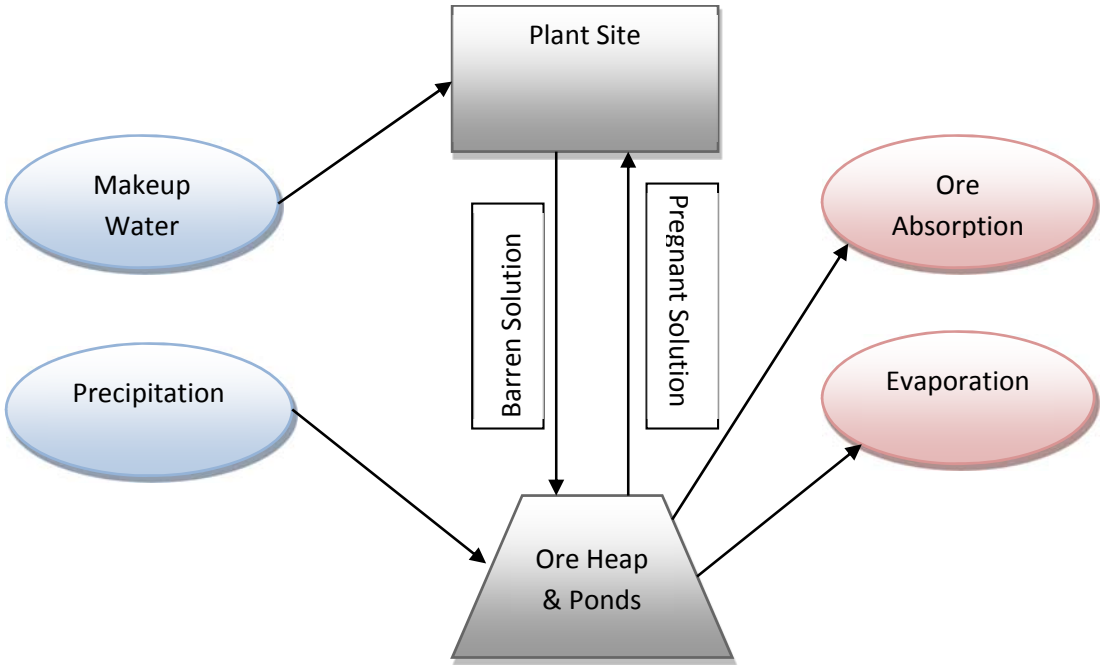
The Squaw Valley site consists of one heap facility that drains to a single PSSA. The Arequa Gulch site includes four different heap phases, each draining to a separate PSSA (named PSSA 1, PSSA 2, PSSA 4, and PSSA 5). Note that Arequa Gulch Phases 2 and 3 drain to the same pond therefore they are combined from a water balance standpoint as Phase 2. The Squaw Valley site was therefore modeled as a single heap and pond while the Arequa Gulch site was modeled with the four pond systems linked together.

The individual Squaw Valley site and the combined Arequa Gulch sites each operate from a water balance standpoint as essentially a "closed" system. Solution is contained within the heap and pond system. Solution from the ponds is pumped to the ADR for processing. In all cases the ponds or Pregnant Solution Storage Areas (PSSAs) are contained within the heaps. Inflows to the system include precipitation and makeup water. Losses include evaporation and loaded ore absorption. **Figure 1** shows a general schematic of the overall flow diagram. This schematic illustrates a single pad and PSSA system such as exists and the Squaw Valley Site. The schematic for the Arequa Gulch site is similar with the difference being that there are four separate heap and PSSAs that all report back to the single process facility.

The water balance estimates solution flow rates from the heap of each facility into the PSSA, PSSA volumes

and makeup demands through active loading and leaching of the facilities plus an eight-year closure period after mining has concluded.

Figure 1 – Water Balance Model Schematic



Model Assumptions/Inputs

Model Setup

A stochastic water balance using variable input precipitation data was developed in GoldSim. A monthly time-step was selected to analyze the water balance as it is short enough to capture critical heap draindown and water uptake resulting from changes in heap height. Monte Carlo simulations were used to predict the range of potential outcomes. The Squaw Valley model simulates 129 months of mining followed by an 8-year post-mining period. The Arequa Gulch model simulates 51 months of mining and also includes 8 years of post-mining conditions. A deterministic analysis was also conducted using mean monthly rainfall data to determine the potential impact of the 100-year, 24-hour storm along with solution draindown during a 12-hour power loss.

Meteorological Data

Monthly precipitation and evaporation data was used in the model. Variation in monthly precipitation formed the basis for variation in the amount of solution stored in the system at a given time. This variability was modeled based on observed precipitation trends at the site so that the model predicted

cycles of wet and dry periods that were consistent with observed precipitation patterns. Monthly mean, standard deviation, and correlation data for precipitation at the mine site was developed using historical data from the site for 1966 through 2010 as presented by AMEC (AMEC 2011). This precipitation data was used in the model. The modeled precipitation data is presented in **Table 1**, showing the monthly mean, standard deviation, and correlation factor for each month. The correlation factor demonstrates how the precipitation in each month of the data set relates to the rainfall observed in the previous month. Monthly precipitation predicted by the model was estimated using the Periodic Auto Regressive method with a one month look back (PAR-1). The 100-year, 24-hour storm depth of 3.50 inches was used for the deterministic analysis.

Table 1 – Modeled Monthly Precipitation Data

Month	Mean (in)	Standard Deviation (in)	Correlation
Jan	0.65	0.45	0.09
Feb	0.55	0.18	0.25
Mar	1.33	0.71	0.46
Apr	1.44	0.87	0.08
May	1.62	0.81	0.23
Jun	1.82	1.09	0.23
Jul	4.22	1.94	0.00
Aug	3.55	1.28	0.11
Sep	1.51	0.45	-0.41
Oct	1.08	0.61	0.32
Nov	0.59	0.40	-0.12
Dec	0.52	0.33	0.24
Annual	18.88	-	-

Monthly runoff coefficients contributing to the PSSA were estimated by ERC for use in the water balance model. Runoff coefficients represent the fraction of total rainfall that will appear as either runoff or drainage for various types of surfaces. These values are shown in **Table 2** below. Precipitation falling on the top of the pad that is not under leach and the side slope areas that is not assumed to runoff or infiltrate into the PSSAs is assumed to be lost from the system through evaporation.

Table 2 – Runoff Coefficients

Surface Type	Runoff Coefficient
Actively leached area on top of the pad	1.0
Non-active leach area on top of the pad	0.3
Heap side slope areas	0.5
Leach pad areas not covered with ore	1.0

Evaporation data was available at the site from 1994 through 1999. Average monthly evaporation values used in the water balance modeling are shown in **Table 3** and are the same values used in previous modeling by AMEC (AMEC 2011). When calculating evaporation losses from the area under leach, an evaporation coefficient of 0.5 was applied in the model based on the leach being applied by a drip system. Evaporative losses were therefore calculated based on the area under leach, the monthly pan evaporation data, and the evaporation coefficient for the drip system application.

Table 3 – Monthly Evaporation Data

Month	Pan Evaporation (in)
Jan	2.23
Feb	2.30
Mar	3.01
Apr	3.35
May	4.43
Jun	6.54
Jul	6.00
Aug	4.78
Sep	3.73
Oct	3.45
Nov	2.40
Dec	2.08
Annual	44.29

Production Data

Monthly lift data describing how much ore is to be added to each heap each month was provided by NewFields. This information is important to the water balance as it impacts losses associated with ore absorption and leaching. Planned loading sequences are provided in **Appendix A**. **Table 4** presents the total ore tonnages are assumed to be placed on each of the heaps. Ore on the heap is assumed to be at a dry density of 110 pounds per cubic foot (pcf).

Table 4 – Tonnages Loaded on Each Heap

Heap	Loaded Ore During Model Duration (million tons)	Previously Placed Ore (million tons)
Squaw Valley	27.6	NA
Arequa Gulch Phase 1	18.3	108.6
Arequa Gulch Phase 2	4.1	100.1
Arequa Gulch Phase 4	7.5	66.3
Arequa Gulch Phase 5	62.0	22.8

Solution Breakthrough and Draindown

Solution movement through the ore upon initial placement and during draindown have been evaluated at the site. A relationship between the height of the ore under leach and the time before breakthrough was evaluated by AMEC (AMEC 2011). The relationship between heap height and the fractional breakthrough of the ore determined by AMEC was used as the basis for estimating this delay. Time required for solution breakthrough incorporated into the water balance model is presented in **Table 5**. It was necessary to round these values to whole months in the model.

Table 5 – Ore Breakthrough Curve

Leached Heap Height (ft)	Time for Full Breakthrough (mon)
200	1
400	2
600	3
800	3

After leaching of an area is complete, that portion of the pad will drain down to its PSSA. The time required for this drainage to occur was found to be a function of heap height. **Table 6** presents the draindown characteristics used in the model, which are based on the calibration work completed by AMEC (AMEC 2011).

Table 6 – Ore Draindown

Leached Heap Height (ft)	Draindown Time (mon)
200	2
400	3
600	4
800	5

Leach Rates and Cycles

Normal rates that leach solution are defined for each heap. Pumps are available to transfer the leach solution and meteorological water that drains to each PSSA for processing. Design leach application rates for solution applied to each heap and pumping capacity for the associated PSSA are presented in **Table 7**.

Table 7 – Solution Application and Maximum Pumping Rates

PSSA	Target Leach Application (gpm)	Maximum Pumping Rate (gpm)
Squaw Valley	17,000	21,200
Arequa Gulch Phase 1	5,200	9,750
Arequa Gulch Phase 2	3,000	7,200
Arequa Gulch Phase 4	4,500	9,900
Arequa Gulch Phase 5	7,400	14,000
Arequa Gulch Total	20,100	40,850

The rate that solution will be applied to the Squaw Valley heap is modeled to range between 0.0025 gpm/ft^2 to 0.0035 gpm/ft^2. At the Arequa Gulch site, the solution application rate is modeled to range from 0.0030 gpm/ft^2 to 0.0045 gpm/ft^2.

For the Squaw Valley site, the total leach rate was calculated as the total top pad area multiplied by the maximum leach application rate of 0.0035 gpm/ft^2 for each month until the total leach rate reached its maximum value of 17,000 gpm. From that point on in the simulation, the leach rate was maintained at 17,000 gpm. Primary leaching was determined based on each month's loaded areas and leach cycles, while secondary leaching was added to other areas of the heap pad to keep the total leach rate constant.

For the Arequa Gulch site, each PSSA was assumed to have the maximum amount of solution possible applied each month, provided that the maximum solution application rates are not exceeded and enough heap area was available at each time step to stay within 0.0030 – 0.0045 gpm/ft^2. The monthly heap heights and corresponding leach cycles were used to estimate the amount of newly leached area for each month.

Based on past performance of the heap the mine has determined the desired leach cycle for newly stacked ore based on the height of the heap under leach. This information was summarized by AMEC (AMEC 2011). The monthly time step used in the water balance model necessitated that desired leach cycles be rounded into monthly values. **Table 8** presents the relationship between heap height and desired leach cycle used in the water balance model.

Table 8 – Leach Cycle for Newly Stacked Ore

Heap Height (ft)	Leach Cycle (days)	Modeled Leach Cycle (months)
50	25	1
100	50	2
150	75	3
200	100	3
250	125	4
300	150	5
350	175	6
400 and greater	200	7

Ore Properties

When new ore is initially leached the moisture content of the ore increases from its placed condition to it's under leach condition. After leaching of an area ceases, the moisture content decreases from it's under leach condition to its field capacity or draindown condition.

Table 9 – Material Properties

Parameter	Value
Ore As-Placed Moisture Content	5.6%
Ore Draindown Moisture Content	7.5%
Ore Leaching Moisture Content	9.5-10%

Heap Geometry

The geometry of the evolving heaps will impact the water balance. NewFields provided data to ERC that broke out the heap into total lined areas, sloped portions of the heap and flat areas. NewFields also provided data on the height of the portion of the heap that was loaded throughout the development of the facility. All of this heap information was input into the model. Detailed heap data and loading data used in the model is presented in **Appendix A**.

PSSA Capacity and Pumping Rates

Capacity curves for each of the PSSA facilities were obtained from NewFields. These are provided in **Appendix B** of this report. Storage capacity within each pond system was based on the assumption that the porosity of the ore in the PSSAs is 35%. The minimum operating volume of PSSAs 1, 2, and 4 at the Arequa Gulch site were provided to be 5.5 million gallons (MG), 3.8 MG, and 6.5 MG, respectively (SWC 2008). Minimum operating volumes were not provided for PSSA 5 of the Arequa Gulch site or for the Squaw Valley PSSA so the minimum volume for these ponds were assumed to be the storage volume that corresponded to a six-foot depth of water in these two PSSAs. This six-foot depth correlates to approximately 2MG in the Squaw Valley PSSA and 700,000 gallons in the Arequa Gulch Phase 5 PSSA.

The pregnant solution storage areas (PSSA) at each site were evaluated to ensure the capacity will be available to hold the summation of the mine's operating volume, along with the greater value of either the solution accumulation due to seasonal climatic variation at a 95% confidence level or the 100-year, 24-hour storm volume plus the draindown volume resulting from 12 hours of power loss given the available pore space of the ore within the PSSAs. The latter scenario was evaluated using mean monthly rainfall data.

As a criterion for evaluating adequacy of storage in each facility, five feet of freeboard was required to be maintained in each PSSA. At the end of each month, ERC assumed that as much of the water in the PSSAs

as possible was pumped out of the ponds, provided that minimum operating volumes were maintained and pumping rates did not exceed pumping capacity (see **Table 7**).

Makeup Water

The model calculated the amount of makeup water required each month based on the net gains or losses to the system. Makeup water was assumed to be added when the amount of water removed from the PSSAs is less than the leach application. Makeup water is not added during closure conditions, which are described in the following section.

Closure

After the conclusion of the 129 months of simulated leaching at the Squaw Valley VLF and 51 months of leaching at the Arequa Gulch sites, the models simulated an 8-year period of post-mining closure conditions. Under closure conditions, makeup water was not added to the system and the amount of water pumped out of the PSSAs each month was added directly back to the top of the heap in the following month. For this time period, it was assumed that solution added to the top of the heap at the start of each month drained immediately to the pond by the end of the month (except for the amount lost to evaporation), without the delay due to breakthrough and draindown that was considered during leaching conditions. This assumption is believed to be valid as areas of the heap receiving this recirculated flow during closure would have been leached at the end of active leaching. The height of the heap receiving the recirculating flows during closure were assumed to remain constant.

During closure the mine will close portions of the heap to reduce the net area that is tributary to each PSSA thereby reducing the total water draining into the ponds. The ratio of top areas to slope areas at the end of active operations were assumed to remain during closure. For the purpose of this evaluation, the area of each heap that is tributary to the PSSA was held constant throughout closure. In reality, the closure heap areas will likely diminish over time as the areas are regraded and reclaimed. The closure areas assumed for each PSSA were reduced to approximately 20-25% of the heap areas before closure. Value used in the modeling are shown in **Table 10**.

Table 10 – Modeled Closure Heap Areas

PSSA	Closure Top Area (ft^2)	Closure Side Slope Area (ft^2)	Total Closure Area (ft^2)
Squaw Valley	750,000	1,750,000	2,500,000
Arequa Gulch 1	276,590	1,036,072	1,312,662
Arequa Gulch 2	124,869	905,445	1,030,314
Arequa Gulch 4	244,692	962,481	1,207,173
Arequa Gulch 5	384,661	1,066,224	1,450,885

Model Results

Results generated by the models are presented below. Results are first presented for the Squaw Valley model and then for the different phases of the Arequa Gulch system. Graphical results from the stochastic

analyses present different colored lines and shading that correspond to statistical results of the Monte Carlo simulations. Mean monthly values are shown by the green line with red dots while median values are illustrated by the blue line. The extents of the light green shading show the range of the 25th and 75th percentile results. Medium green shading illustrates the range of the 5th and 95th percentile values while the top and bottom of the shaded areas show the range of the lower and upper bound results. The same color and percentile scheme is used for all result figures below.

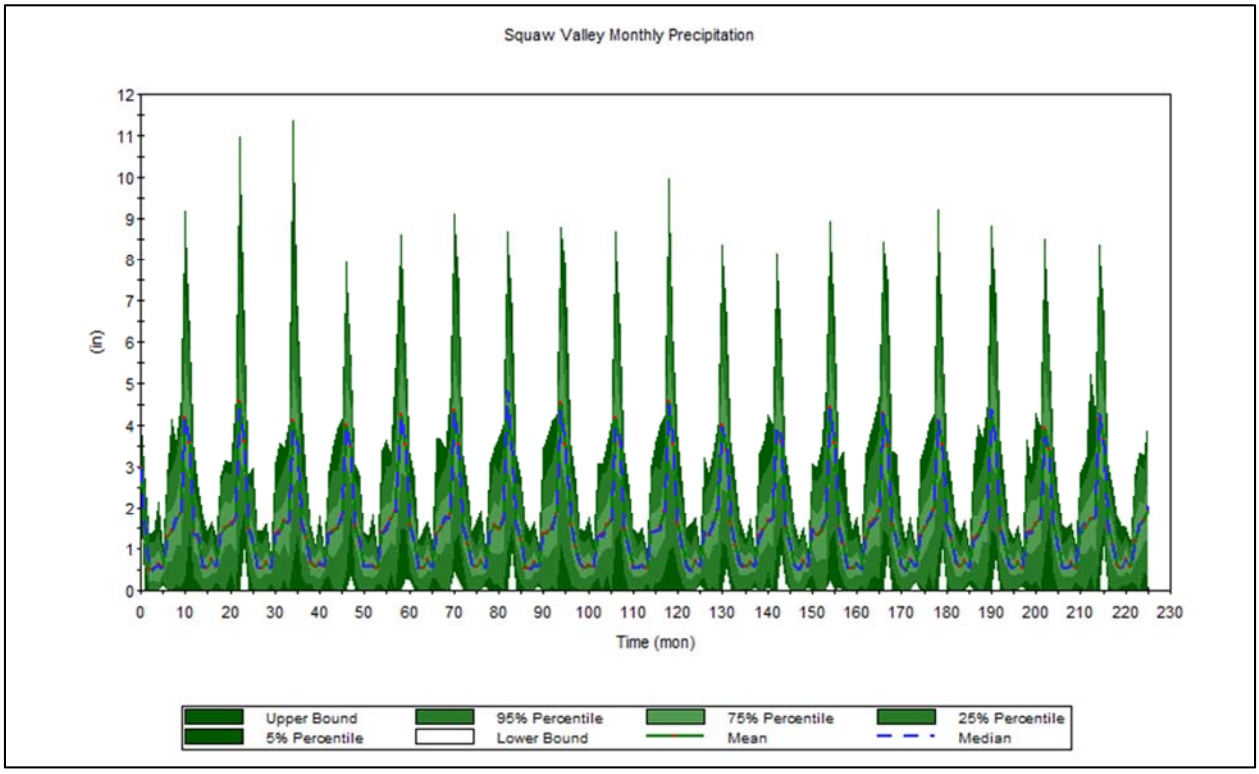
Results are also provided for each site considering the runoff from the 100-yer, 24-hour event along with the draindown due to 12 hours of power loss. For this scenario, the average monthly precipitation was used instead of the Monte Carlo distribution of rainfall data. The required capacity of the PSSA ponds is equal to the greater value of either the volume generated by this simulation or the 95th percentile volume from the stochastic analysis.

Squaw Valley VLF Stochastic Results

Monthly Precipitation

Monthly precipitation values generated by the model are presented in **Figure 2**. As is expected based on observed regional data, mean monthly precipitation values range from approximately 0.5 inches during winter months to over 4 inches in July. Peak monthly precipitation predicted by the model exceed 8 inches during each summer of the model simulation; the overall single peak month precipitation generated by the model is approximately 11.5 inches. Note that the variability in precipitation drives the variations in other values calculated by the model.

Figure 2 – Squaw Valley Monthly Precipitation

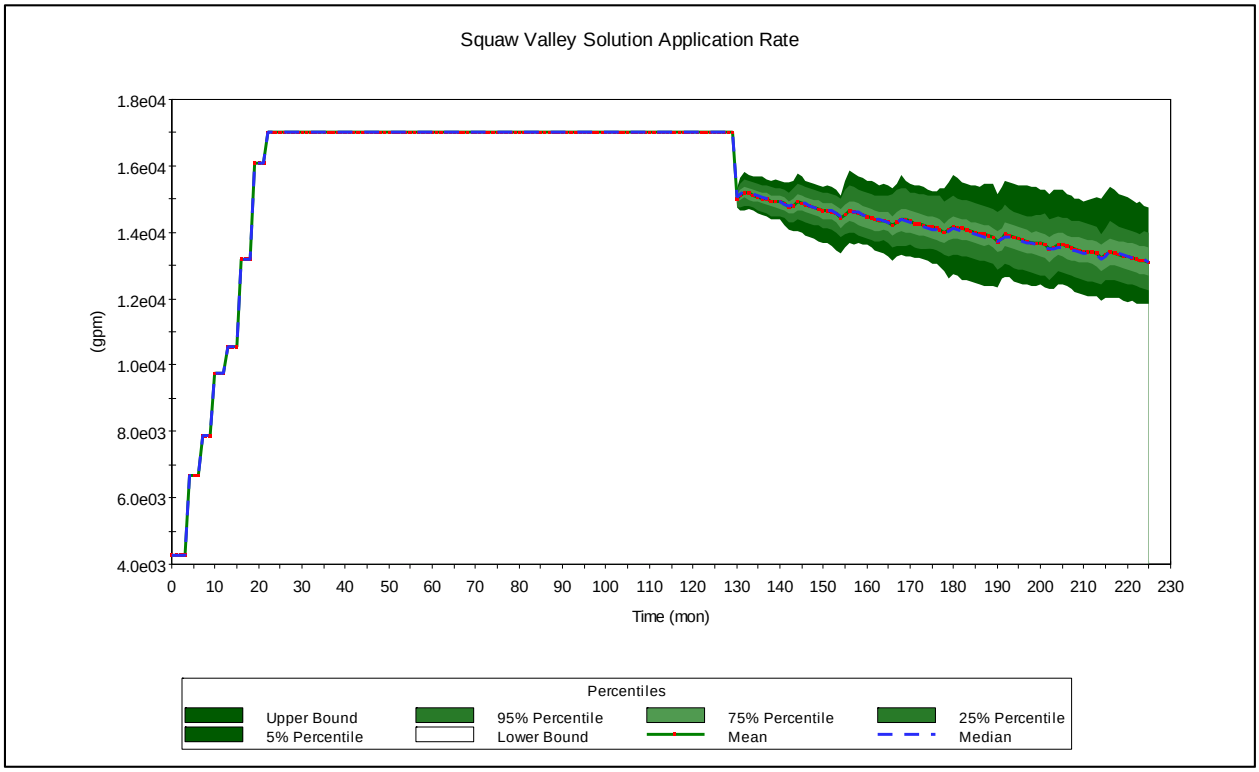


Solution Application

The total solution predicted to be applied to the top of the Squaw Valley heap is presented in **Figure 3**. During the first 20 months of operations, the total application rate is predicted to be less than 17,000 gpm. This is the result of the limited area that is available to apply solution as the heap initially expands. Over time as the area available for leaching increases, the solution application will approach 17,000 gpm. Once it reaches 17,000 gpm it stays at this level throughout the remainder of operations until closure begins.

During closure the applied solution is predicted to decrease. Based on average precipitation conditions, over the 8-year closure period modeled the solution rate is predicted to decrease to roughly 13,000 gpm. Flows could be reduced even further if a greater portion of the heap were to be closed.

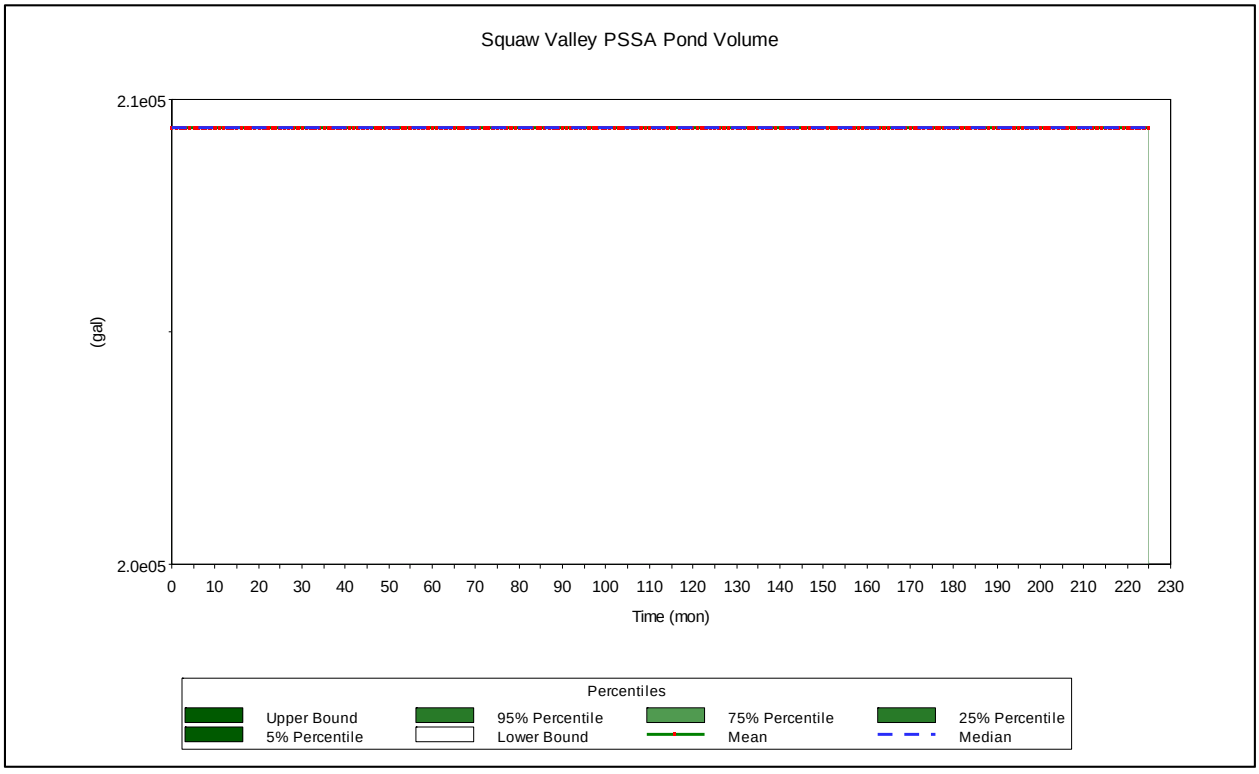
Figure 3 – Squaw Valley Solution Application Rate



Pond Storage and Remaining Freeboard

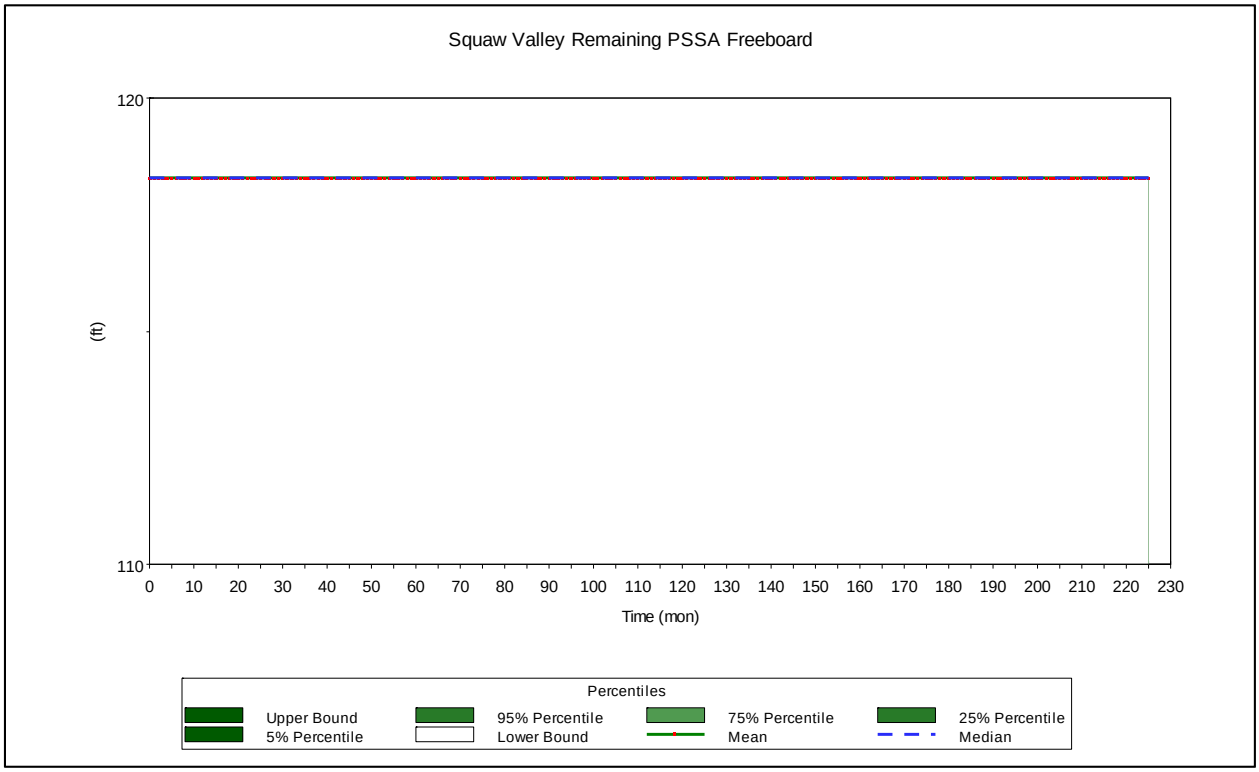
The amount of solution predicted to be in the PSSA at the end of each month is presented in **Figure 4**. Because the maximum pump rate from **Table 7** is greater than the amount of solution being applied for all months, it is expected that solution levels can be maintained at the PSSA's minimum level throughout operations and closure.

Figure 4 – Squaw Valley PSSA Pond Volume



Remaining freeboard is the total PSSA capacity minus the amount of water predicted to be stored at any time. **Figure 5** illustrates the amount of freeboard expected to remain during active leaching and closure. Because the pond is maintained at its minimum volume throughout the simulation, the amount of freeboard in the pond is at its maximum value of just over 118 feet for the entire length of the simulation.

Figure 5 – Squaw Valley Remaining PSSA Freeboard

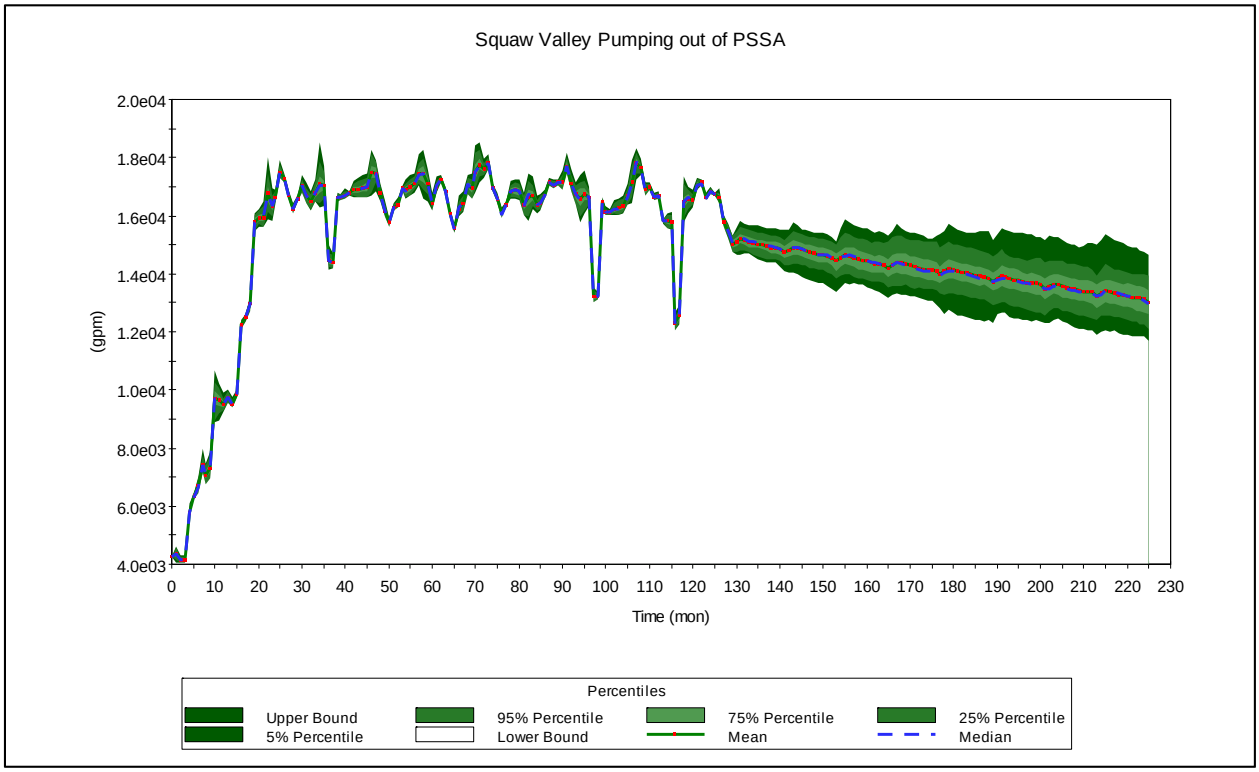


Pumping from Squaw Valley PSSA

The amount of solution predicted to be pumped from the PSSA for processing is presented in **Figure 6**. During the first year and a half of operations the calculated pumping closely follows the startup application rates presented in **Figure 3**. After the steady state application rate is achieved, pumping from the PSSA will generally vary between 16,000 and 18,000 gpm. At approximately months 97 and 116, pumping from the PSSA is predicted to drop to approximately 12,000 – 13,000 gpm. These temporary decreases are the result of lower heap drainage inflows and changing heap heights under leach.

During closure the applied solution is predicted to decrease, resulting in a decrease in pumping. Solution pumped out of the PSSA during closure is assumed to be the amount of solution applied back to the top of the heap. Based on average precipitation conditions, over the 8-year closure period modeled the pumping and applied solution is predicted to decrease to roughly 13,000 gpm. Flows could be reduced even further if a greater portion of the heap were to be closed.

Figure 6 – Squaw Valley Pumping out of PSSA

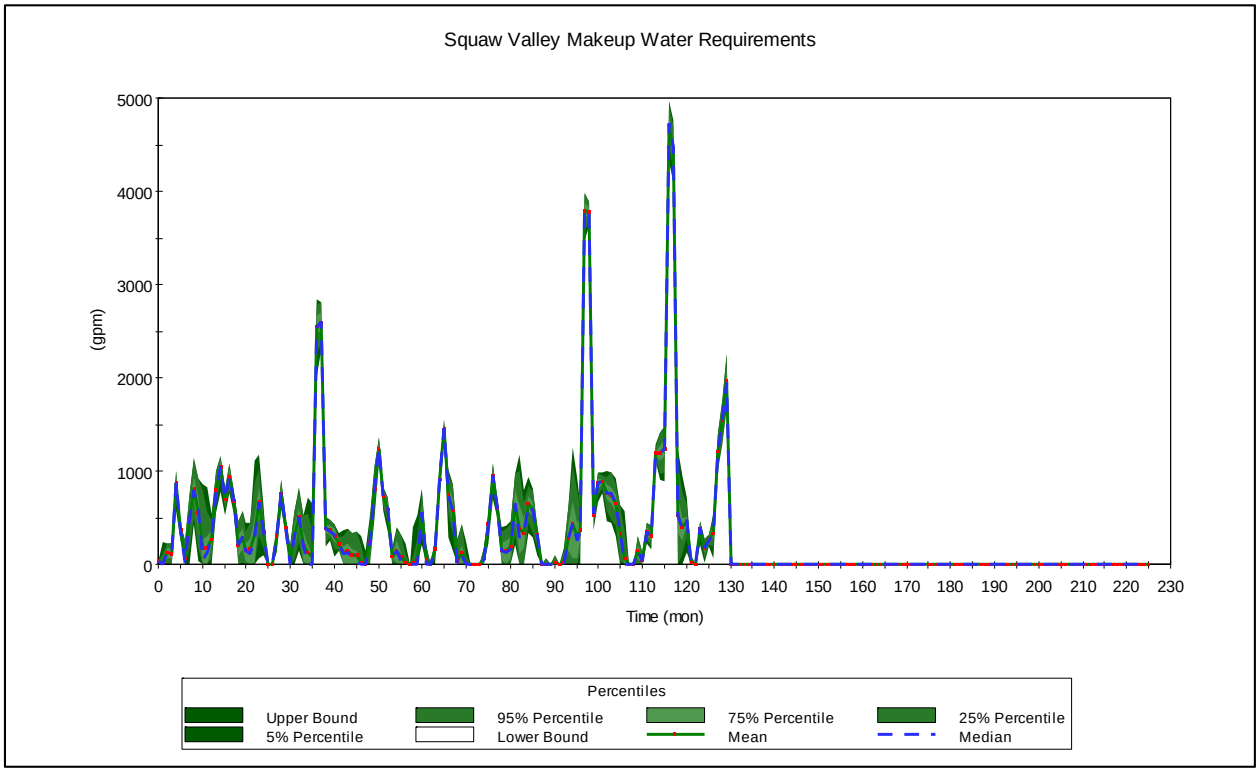


Makeup Water

Makeup water represents the amount of outside water that is predicted to be required in order to maintain the desired application rate. Makeup estimates for the Squaw Valley site are presented in **Figure 7**. Makeup water is directly related to pumping out of the PSSA shown in **Figure 6** in that any time the predicted pumping is less than the desired application rate, makeup water is added to the system to make up the difference.

Typical makeup water requirements will vary from little to no water up to approximately 1,000 gpm. Four short duration spikes in makeup water are predicted by the model with the peak single month value on the order of 2,000 – 5,000 gpm. All spikes are the result of loading, leaching, and differences in heap heights. Once the system moves into closure, no additional makeup water will be required.

Figure 7 – Squaw Valley Makeup Water Requirements



Squaw Valley VLF Results with 100-Year Runoff and Draindown Due to Power Loss

The amount of solution in the PSSA at the end of each month due to mean precipitation plus runoff from the 100-year, 24-hour event and draindown due to 12 hours of power loss is shown in **Figure 8** and freeboard in the pond under these conditions is shown in **Figure 9**. This simulation predicts total solution in the pond immediately after the storm and draindown event so a volume of solution greater than the minimum operating volume is generated for each month, even after closure. The minimum freeboard in the pond in this simulation is determined to be approximately 75 feet, and approaches 100 feet after closure takes place.

Figure 8 – Squaw Valley PSSA Pond Volume with the 100-year, 24-hour Runoff and Draindown Due to Power Loss

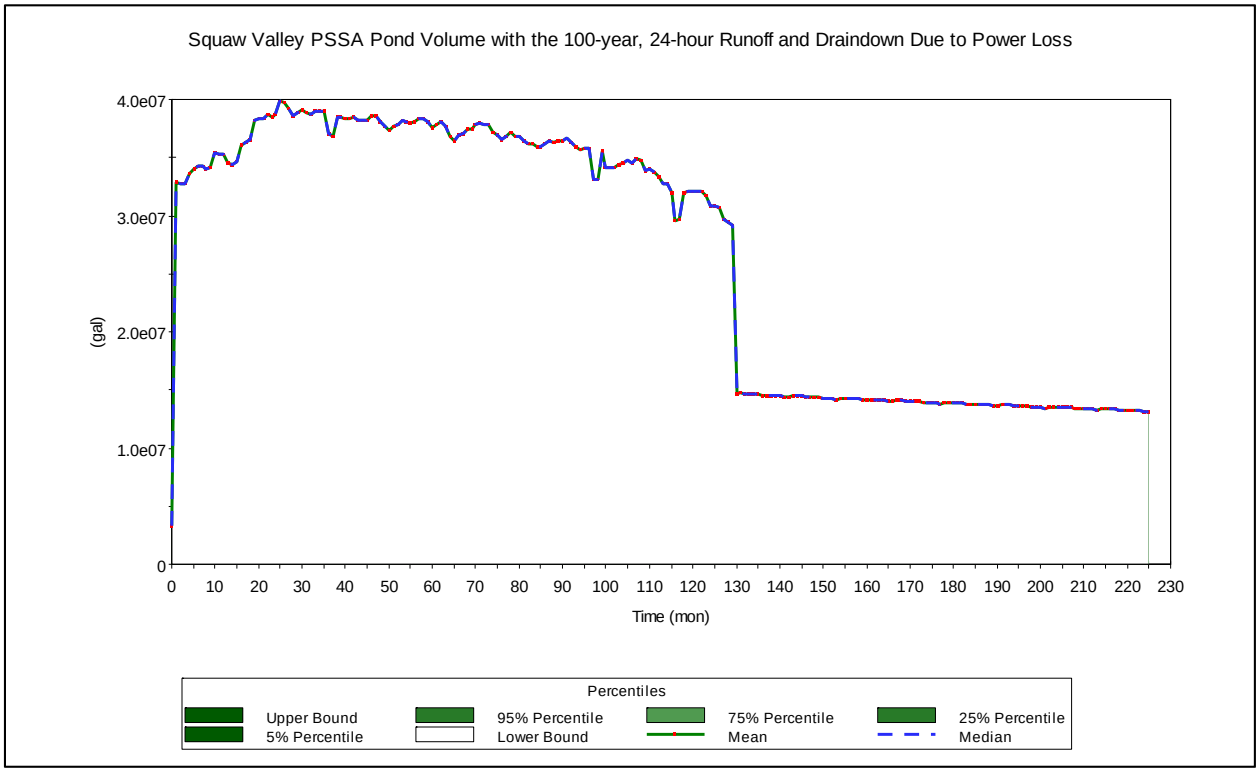
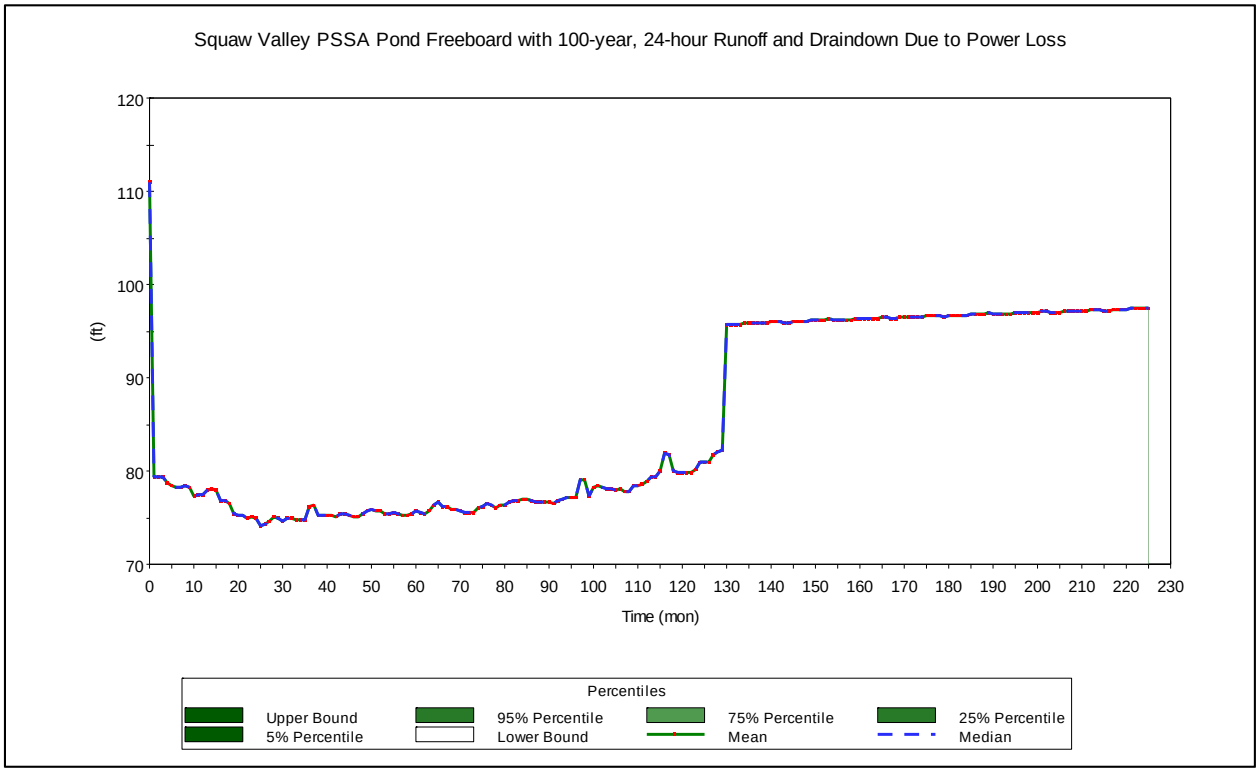


Figure 9 – Squaw Valley PSSA Pond Freeboard with 100-year, 24-hour Runoff and Draindown Due to Power Loss



Arequa Gulch VLF Stochastic Results

Monthly Precipitation

Modeled monthly precipitation at the Arequa Gulch site is the same as that used for the Squaw Valley site (see **Figure 2**). Mean monthly precipitation values range from approximately 0.5 inches during winter months to over 4 inches in July. Peak monthly precipitation predicted by the model exceed 8 inches during each summer of the model simulation; the overall single peak month precipitation generated by the model is approximately 11.5 inches. Note that the variability in precipitation drives the variations in other values calculated by the model.

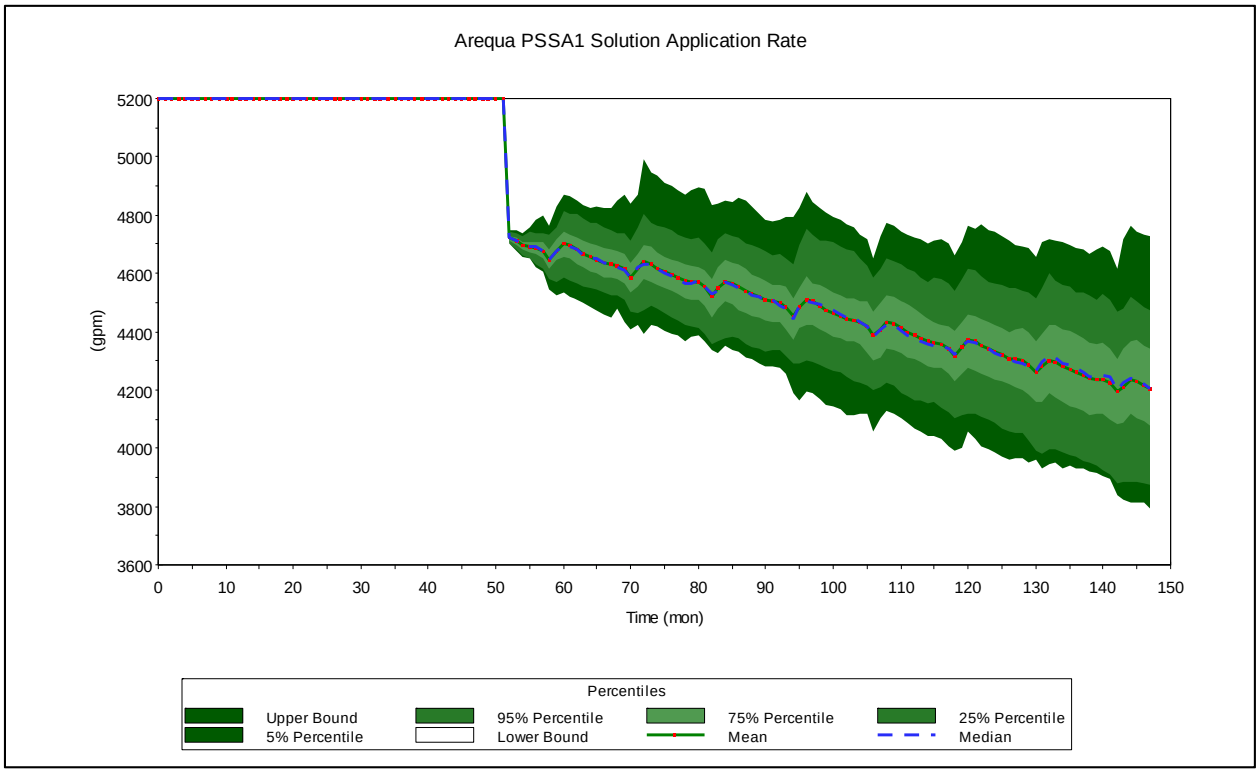
Arequa Gulch Phase 1 Results

Solution Application

The total solution predicted to be applied to the top of the Arequa Gulch Phase 1 heap is presented in **Figure 10**. Results show that during operations solution is predicted to be applied to the top of the heap at a constant rate of 5,200 gpm.

During closure the applied solution is predicted to decrease. Based on average precipitation conditions, over the 8-year closure period modeled the solution rate is predicted to decrease to roughly 4,300 gpm. Flows could be reduced even further if a greater portion of the heap were to be closed.

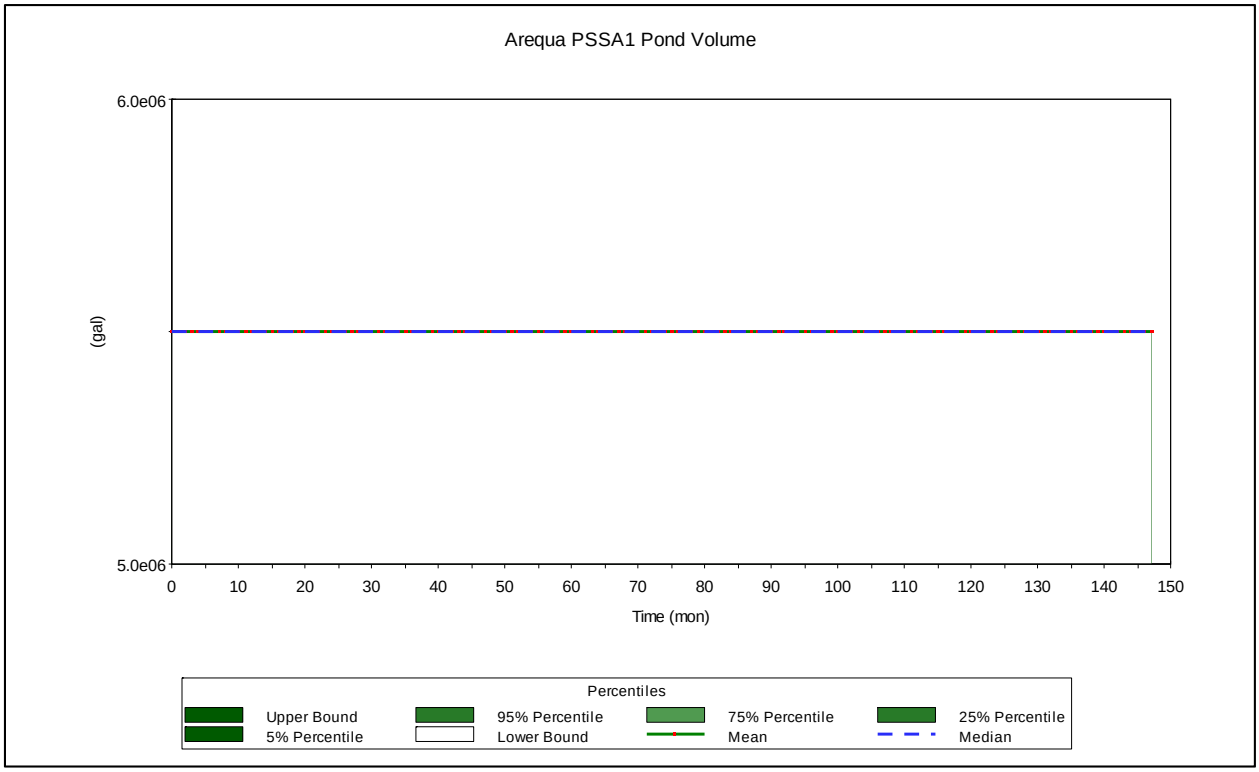
Figure 10 – Arequa Gulch PSSA1 Solution Application Rate



Pond Storage and Remaining Freeboard

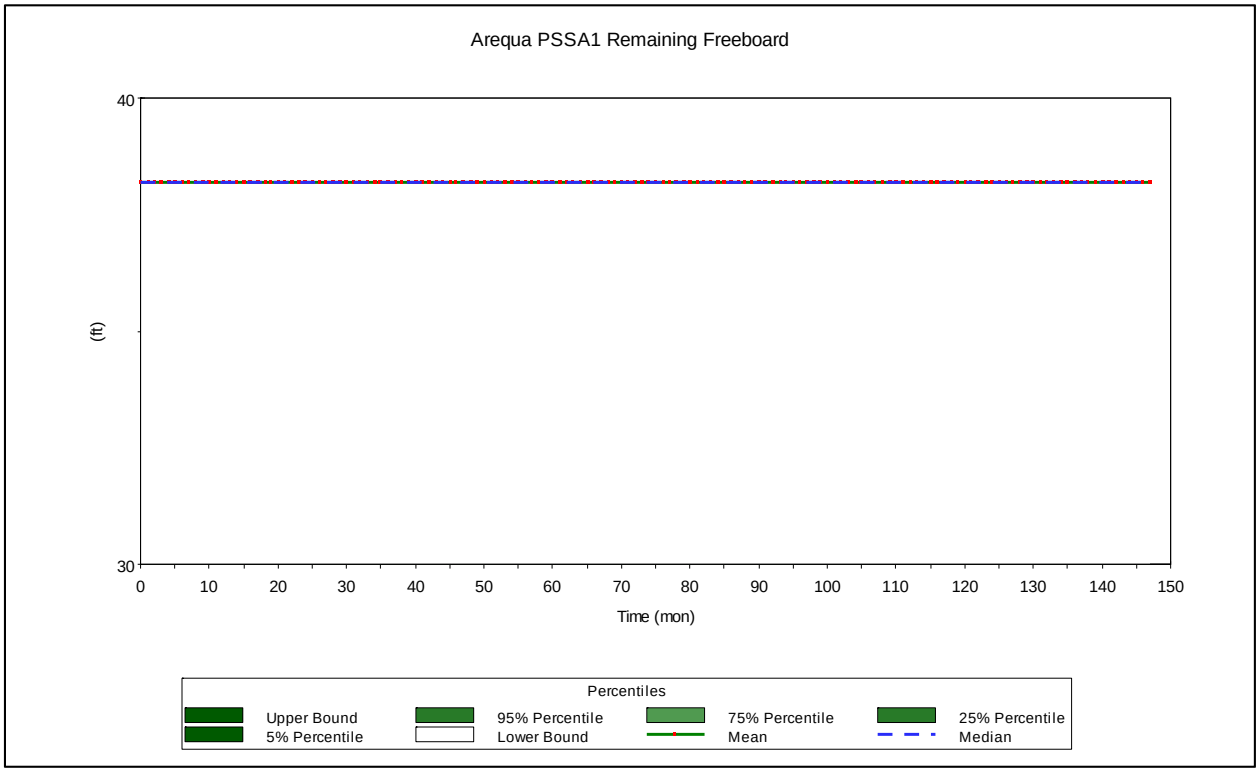
The amount of solution predicted to be in the PSSA at the end of each month is presented in **Figure 11**. In all months modeled the net water loss predicted exceeds the net inflow therefore it is expected that solution levels can be maintained at the PSSAs minimum level throughout operations and closure.

Figure 11 – Arequa Gulch PSSA1 Pond Volume



Remaining freeboard is the total PSSA capacity minus the amount of water predicted to be stored at any time. **Figure 12** illustrates the amount of freeboard expected to remain during active leaching and closure. As the amount of water predicted to be stored in the pond is a constant, remaining freeboard is also a constant. Approximately 38 feet of freeboard is predicted to remain in the PSSA.

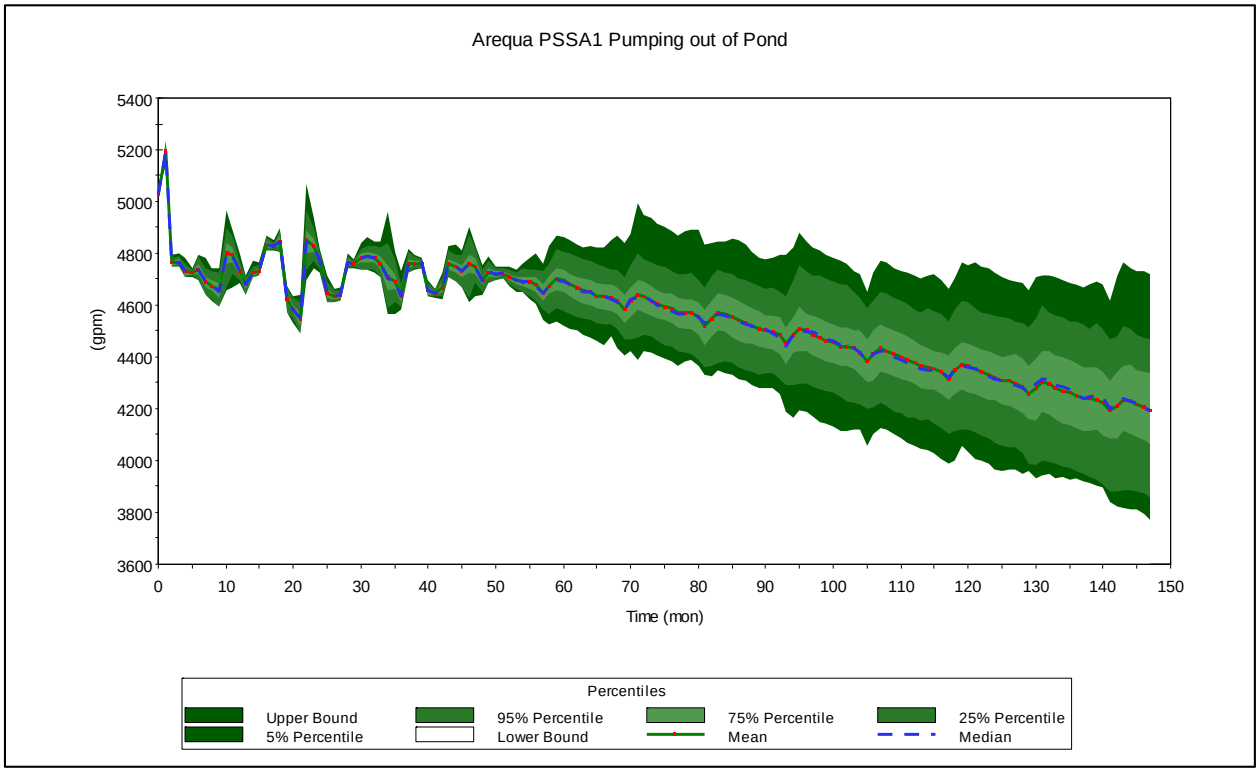
Figure 12 – Arequa Gulch PSSA1 Remaining Freeboard



Pumping from Arequa Gulch PSSA 1

The amount of solution predicted to be pumped from the PSSA for processing is presented in **Figure 13**. During operations when the amount of solution applied to the heap is 5,200 gpm, an average of approximately 4,700 gpm is expected to be available for pumping to the process facility. Once the facility switches to closure the pumping is expected to steadily decrease with a final value on the order of 4,200 gpm predicted after eight years.

Figure 13 – Arequa Gulch PSSA1 Pumping out of Pond



Makeup Water

Given that all of the Arequa Gulch PSSAs convey water to a single point for processing, the amount of makeup water required at Arequa Gulch is a function of operations at the system as a whole and isn't determined for each individual heap and pond system. The total amount of makeup water predicted to be required at Arequa Gulch is presented below on **Figure 24** after the results for the Arequa Gulch Phase 5 system.

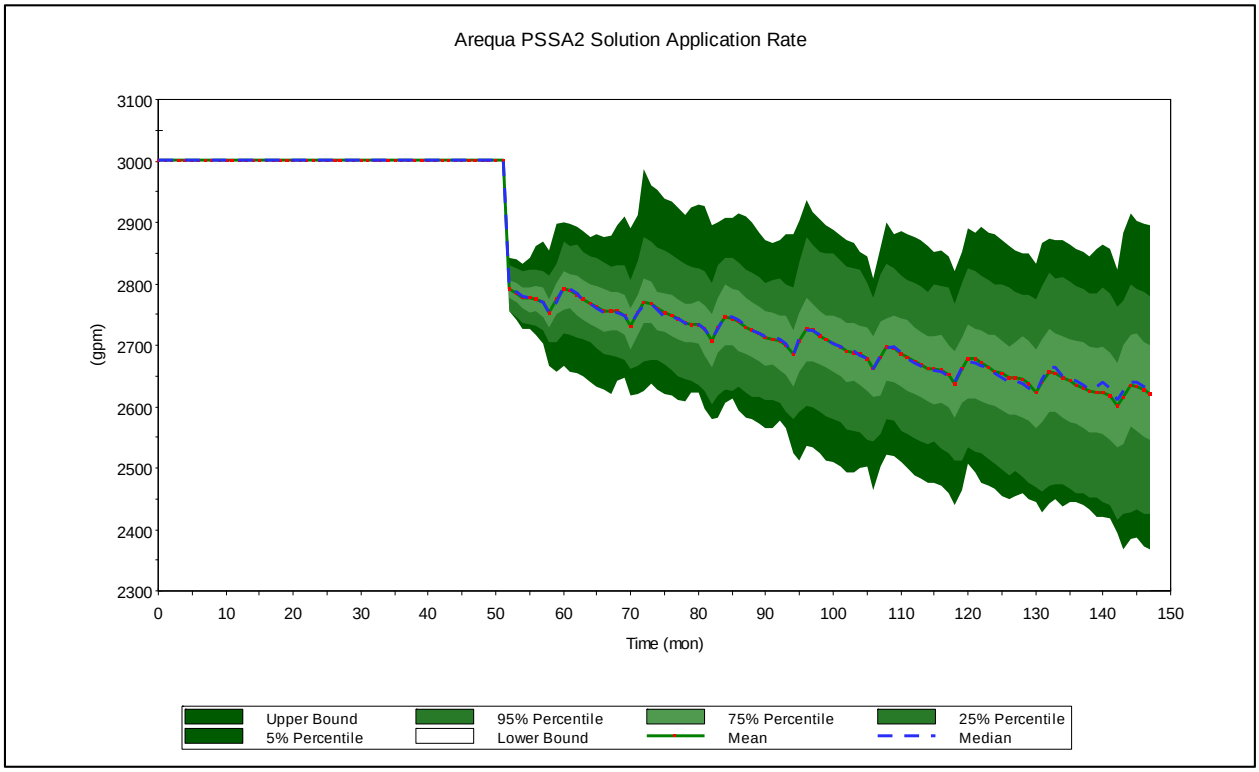
Arequa Gulch Phase 2 Results

Solution Application

The total solution predicted to be applied to the top of the Arequa Gulch Phase 2 heap is presented in **Figure 14**. Results show that during operations solution is predicted to be applied to the top of the heap at a constant rate of 3,000 gpm.

During closure the applied solution is predicted to decrease. Based on average precipitation conditions, over the 8-year closure period modeled the solution rate is predicted to decrease to roughly 2,650 gpm. Flows could be reduced even further if a greater portion of the heap were to be closed.

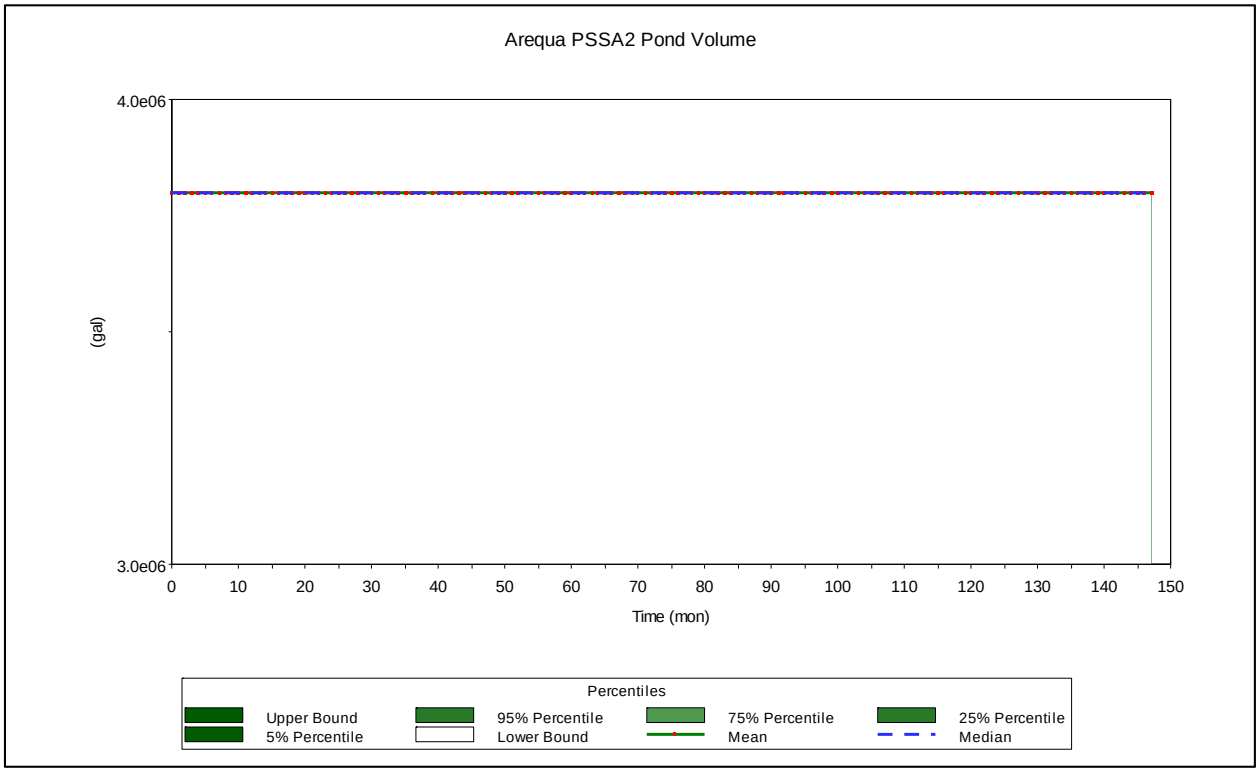
Figure 14 – Arequa Gulch PSSA2 Solution Application Rate



Pond Storage and Remaining Freeboard

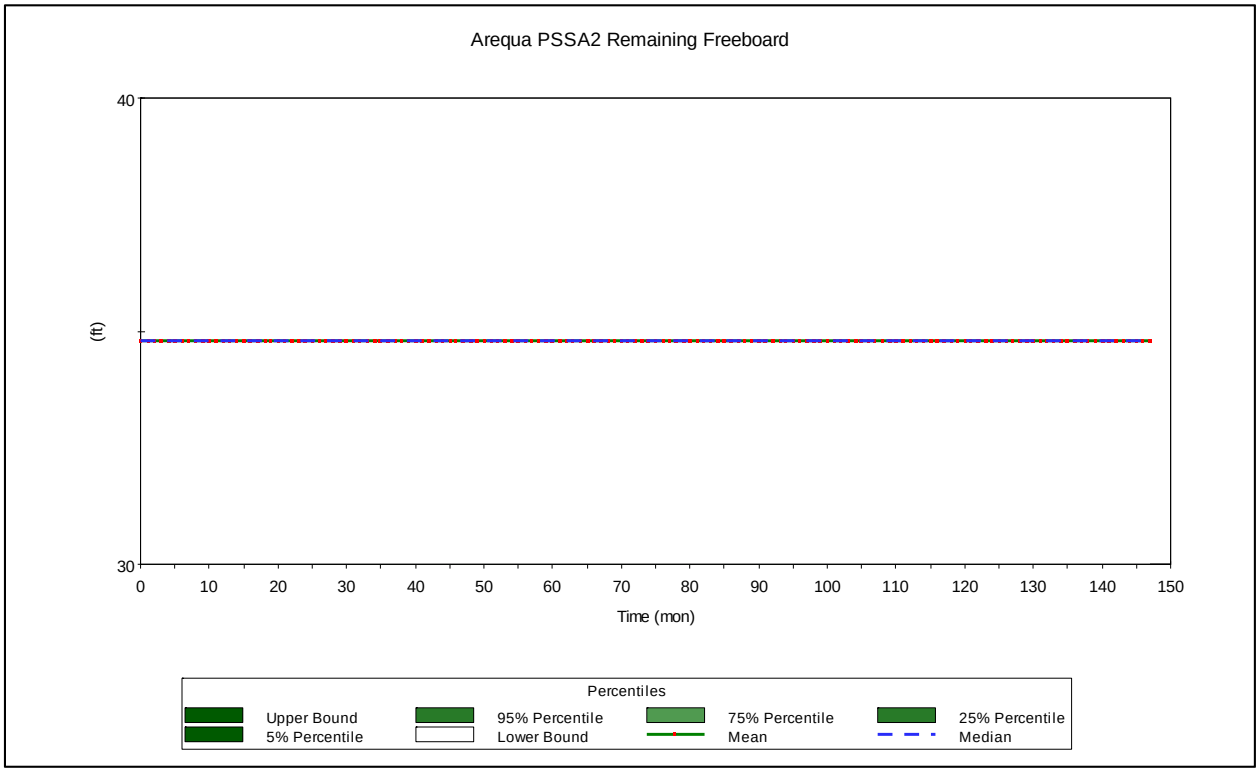
The amount of solution predicted to be in the PSSA at the end of each month is presented in **Figure 15**. In all months modeled the net water loss predicted exceeds the net inflow therefore it is expected that solution levels can be maintained at the PSSAs minimum level throughout operations and closure.

Figure 15 – Arequa Gulch PSSA2 Pond Volume



Remaining freeboard is the total PSSA capacity minus the amount of water predicted to be stored at any time. **Figure 16** illustrates the amount of freeboard expected to remain during active leaching and closure. As the amount of water predicted to be stored in the pond is a constant, remaining freeboard is also a constant. Approximately 35 feet of freeboard is predicted to remain in the PSSA.

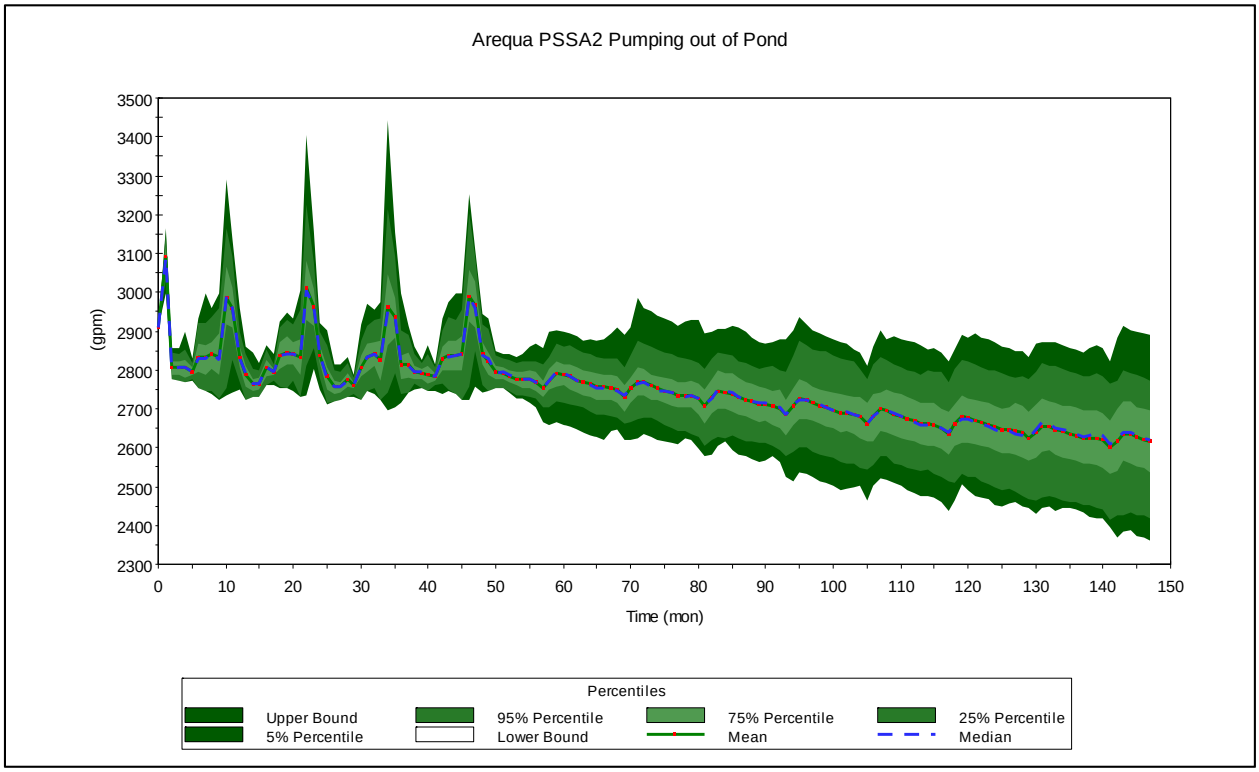
Figure 16 – Arequa Gulch PSSA2 Remaining Freeboard



Pumping from Arequa Gulch PSSA 2

The amount of solution predicted to be pumped from the PSSA for processing is presented in **Figure 17**. During operations when the amount of solution applied to the heap is 3,000 gpm, an average of approximately 2,850 gpm is expected to be available for pumping to the process facility. Once the facility switches to closure the pumping is expected to steadily decrease with a final value on the order of 2,650 gpm predicted after eight years.

Figure 17 – Arequa Gulch PSSA2 Pumping out of Pond



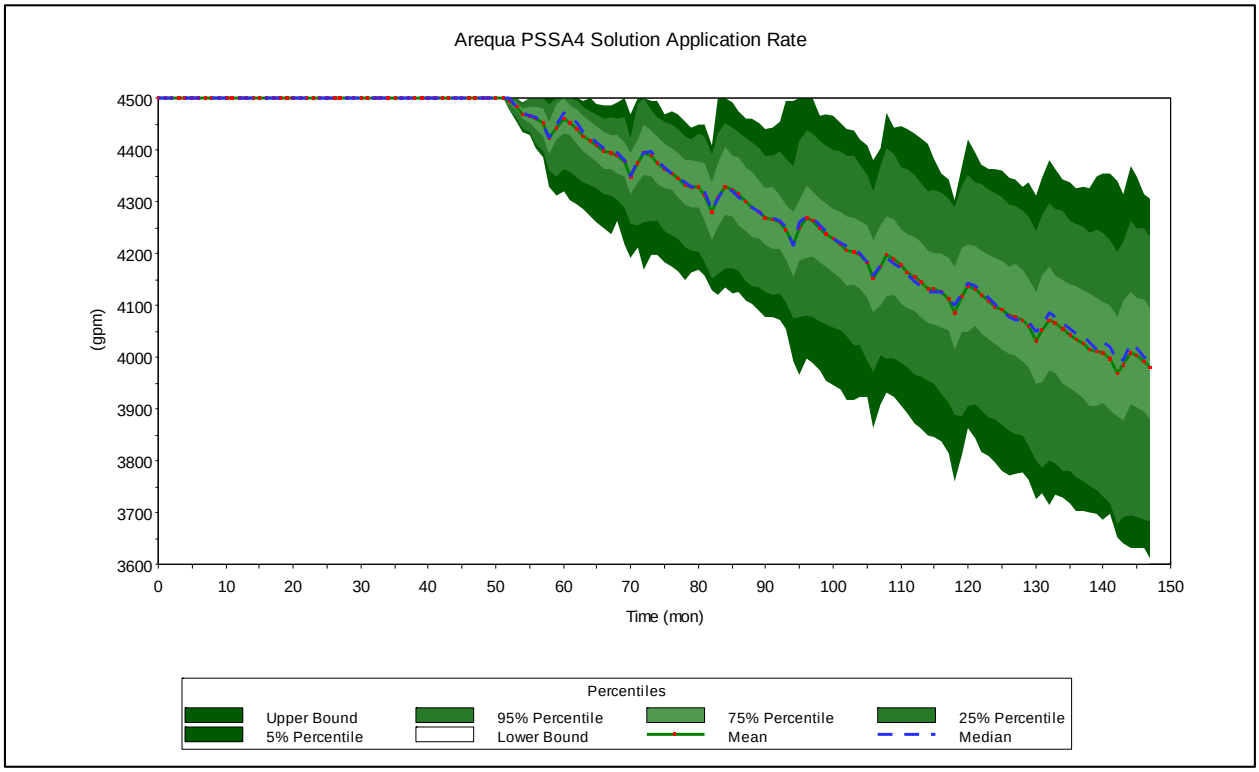
Arequa Gulch Phase 4 Results

Solution Application

The total solution predicted to be applied to the top of the Arequa Gulch Phase 4 heap is presented in **Figure 18**. Results show that during operations solution is predicted to be applied to the top of the heap at a constant rate of 4,500 gpm.

During closure the applied solution is predicted to decrease. Based on average precipitation conditions, over the 8-year closure period modeled the solution rate is predicted to decrease to roughly 4,000 gpm. Flows could be reduced even further if a greater portion of the heap were to be closed.

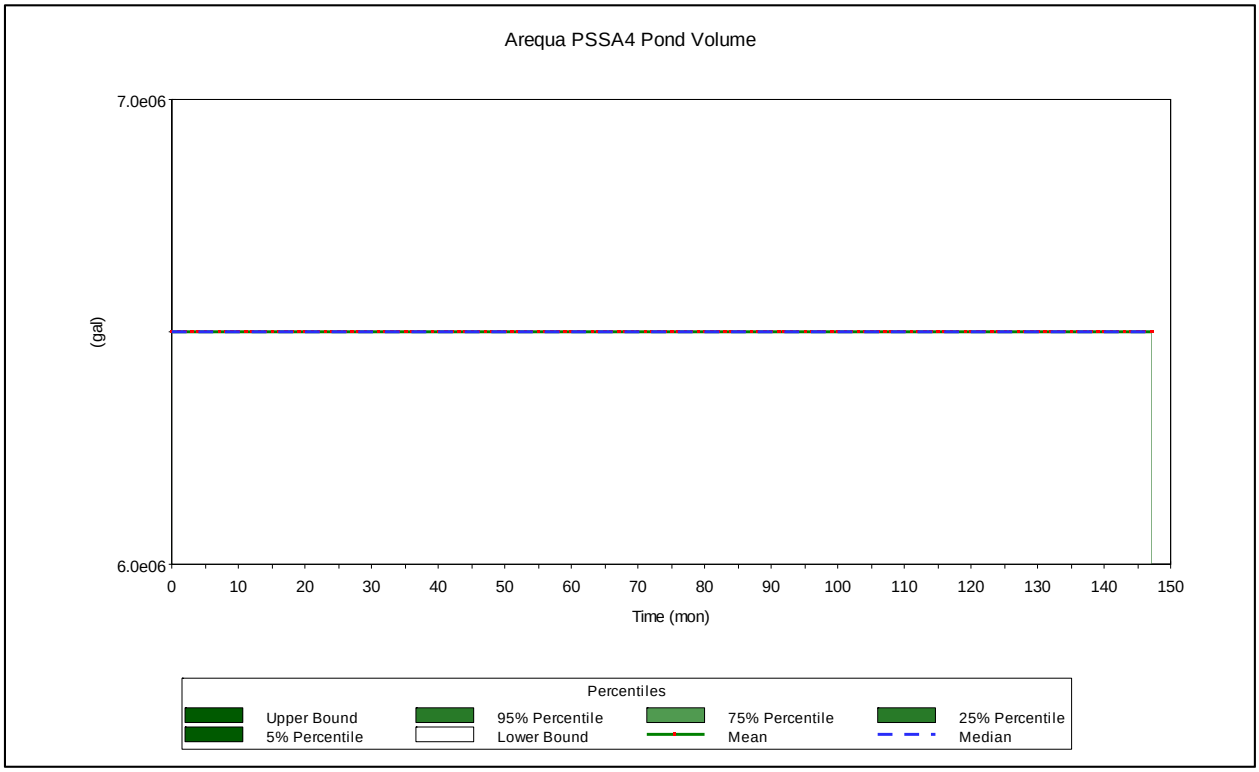
Figure 18 – Arequa Gulch PSSA4 Solution Application Rate



Pond Storage and Remaining Freeboard

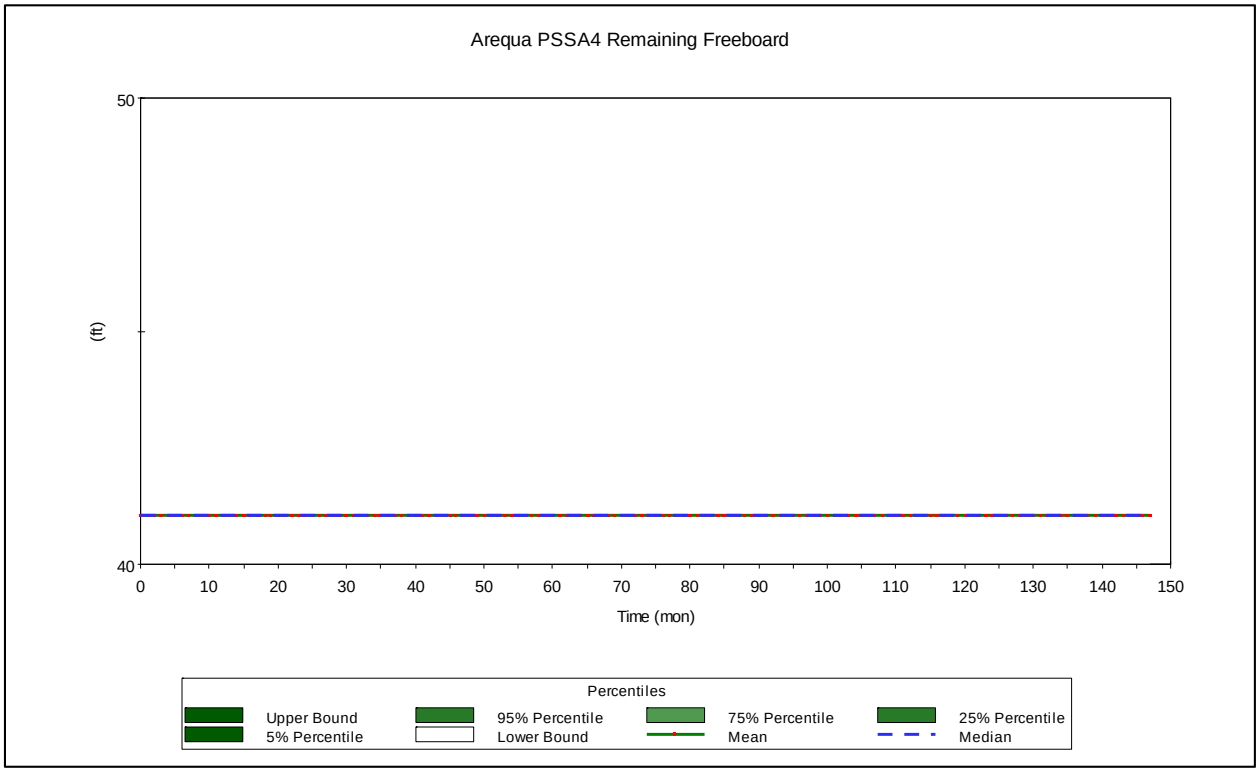
The amount of solution predicted to be in the PSSA at the end of each month is presented in **Figure 19**. In all months modeled the net water loss predicted exceeds the net inflow therefore it is expected that solution levels can be maintained at the PSSAs minimum level throughout operations and closure.

Figure 19 – Arequa Gulch PSSA4 Pond Volume



Remaining freeboard is the total PSSA capacity minus the amount of water predicted to be stored at any time. **Figure 20** illustrates the amount of freeboard expected to remain during active leaching and closure. As the amount of water predicted to be stored in the pond is a constant, remaining freeboard is also a constant. Approximately 41 feet of freeboard is predicted to remain in the PSSA.

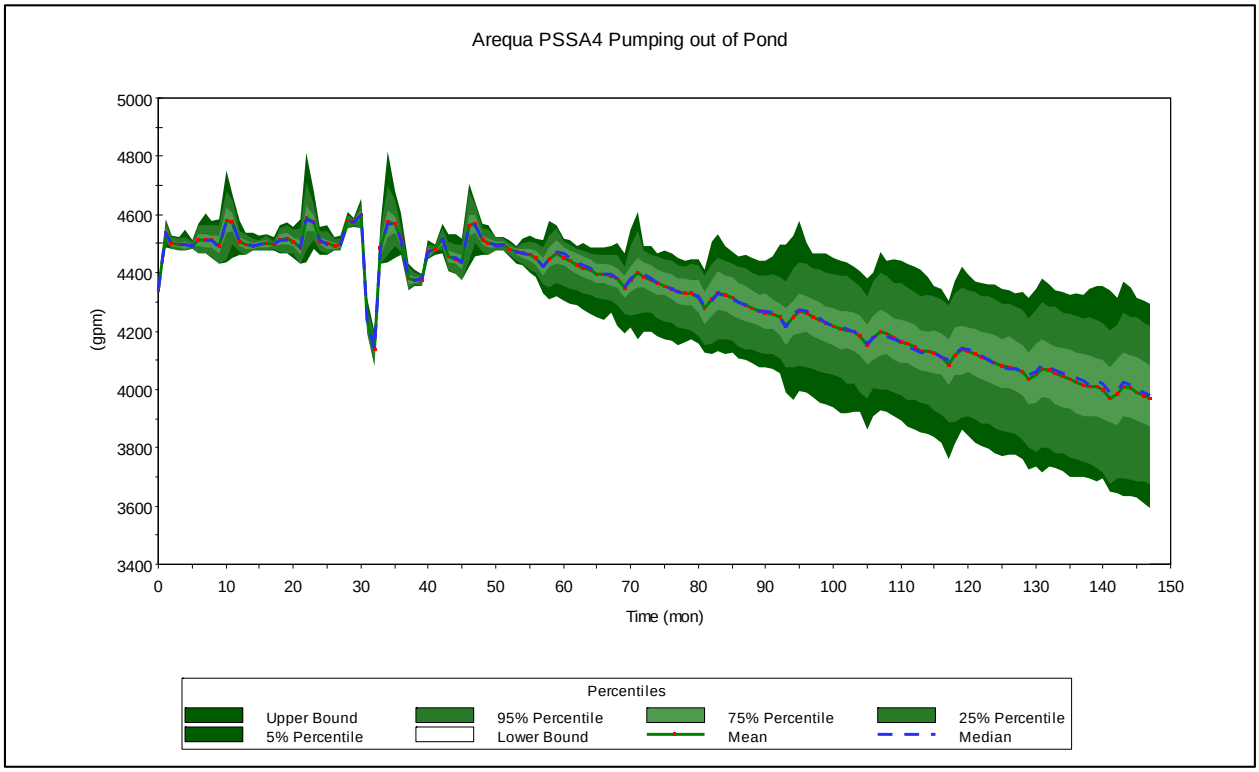
Figure 20 – Arequa Gulch PSSA4 Remaining Freeboard



Pumping from Arequa Gulch PSSA 4

The amount of solution predicted to be pumped from the PSSA for processing is presented in **Figure 21**. During operations when the amount of solution applied to the heap is 4,500 gpm, an average of approximately 4,500 gpm is expected to be available for pumping to the process facility. Once the facility switches to closure the pumping is expected to steadily decrease with a final value on the order of 4,000 gpm predicted after eight years.

Figure 21 – Arequa Gulch PSSA4 Pumping out of Pond



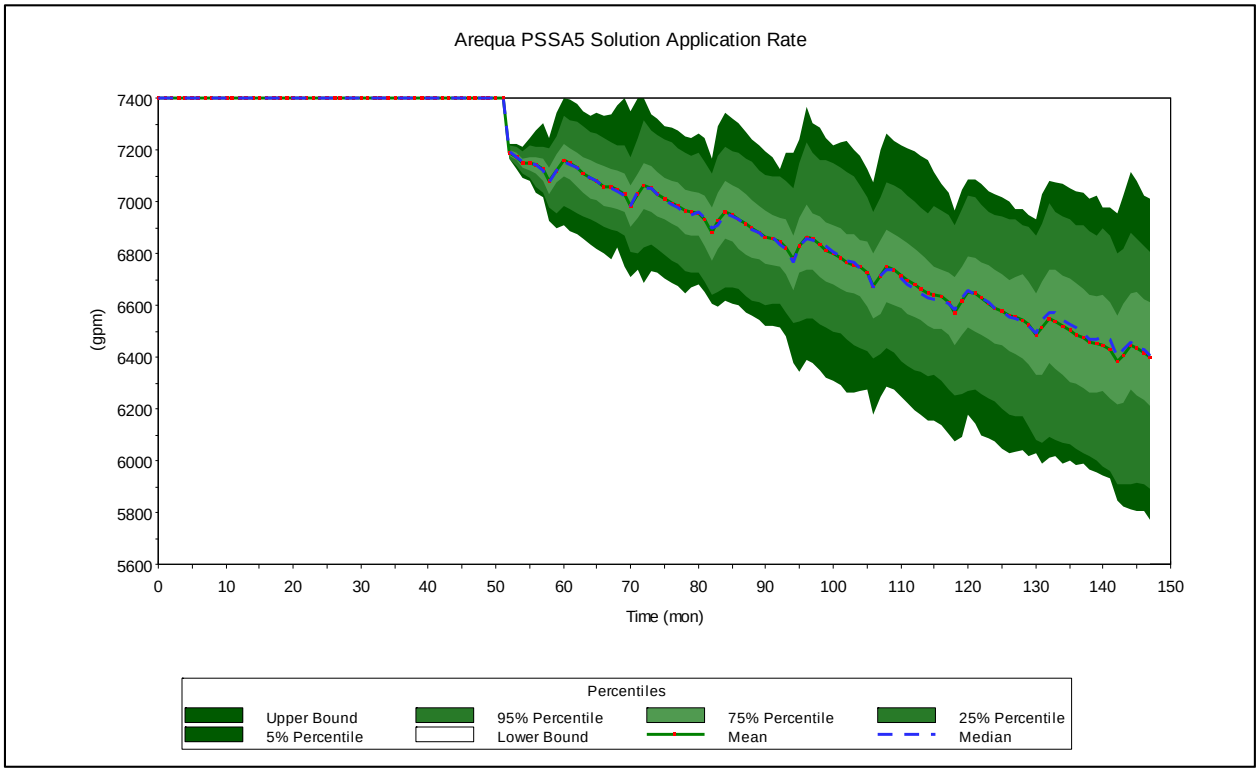
Arequa Gulch Phase 5 Results

Solution Application

The total solution predicted to be applied to the top of the Arequa Gulch Phase 5 heap is presented in **Figure 22**. Results show that during operations solution is predicted to be applied to the top of the heap at a constant rate of 7,400 gpm.

During closure the applied solution is predicted to decrease. Based on average precipitation conditions, over the 8-year closure period modeled the solution rate is predicted to decrease to roughly 6,400 gpm. Flows could be reduced even further if a greater portion of the heap were to be closed.

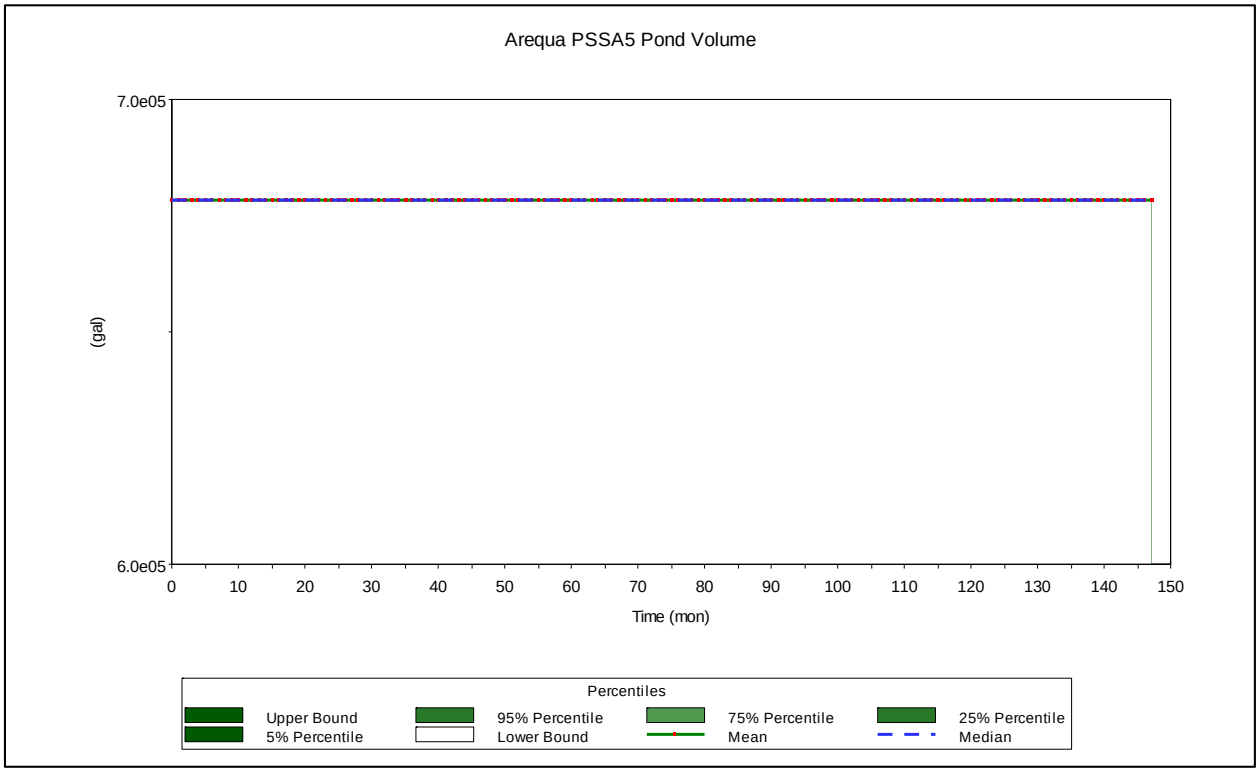
Figure 22 – Arequa Gulch PSSA5 Solution Application Rate



Pond Storage and Remaining Freeboard

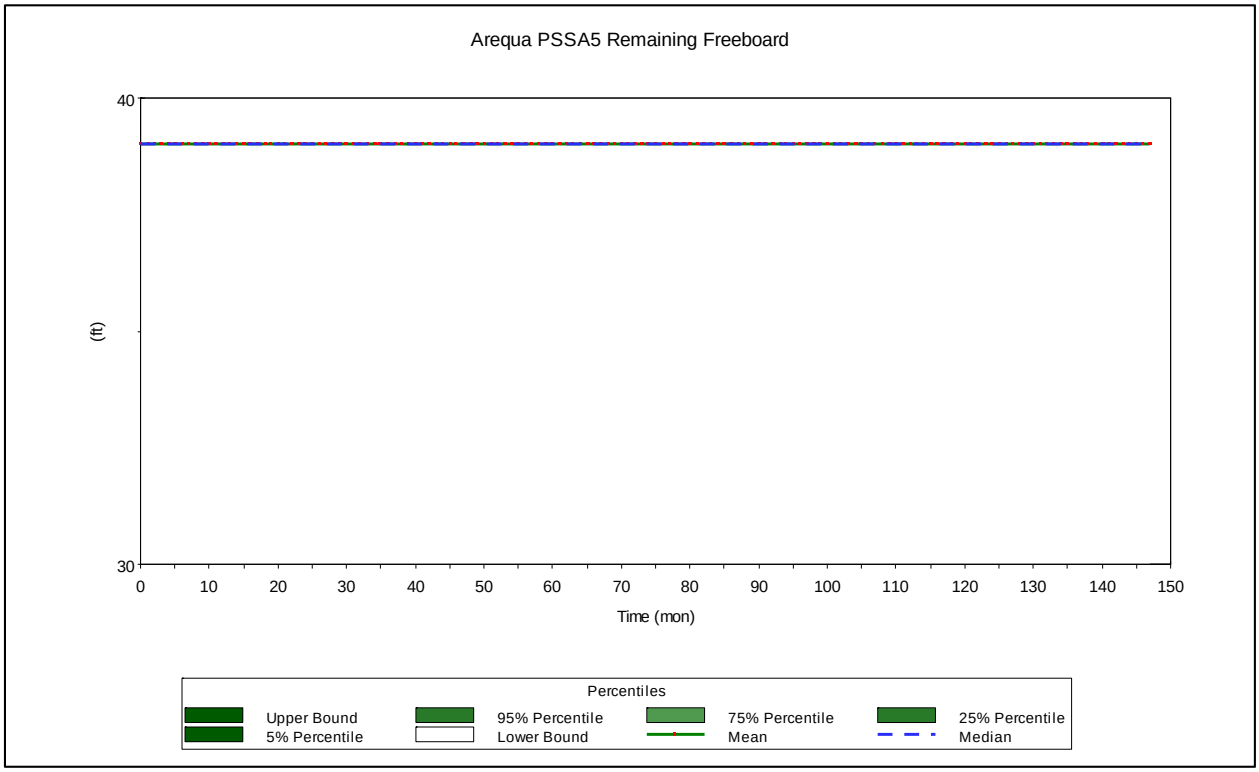
The amount of solution predicted to be in the PSSA at the end of each month is presented in **Figure 23**. In all months modeled the net water loss predicted exceeds the net inflow therefore it is expected that solution levels can be maintained at the PSSAs minimum level throughout operations and closure.

Figure 23 – Arequa Gulch PSSA5 Pond Volume



Remaining freeboard is the total PSSA capacity minus the amount of water predicted to be stored at any time. **Figure 24** illustrates the amount of freeboard expected to remain during active leaching and closure. As the amount of water predicted to be stored in the pond is a constant, remaining freeboard is also a constant. Approximately 39 feet of freeboard is predicted to remain in the PSSA.

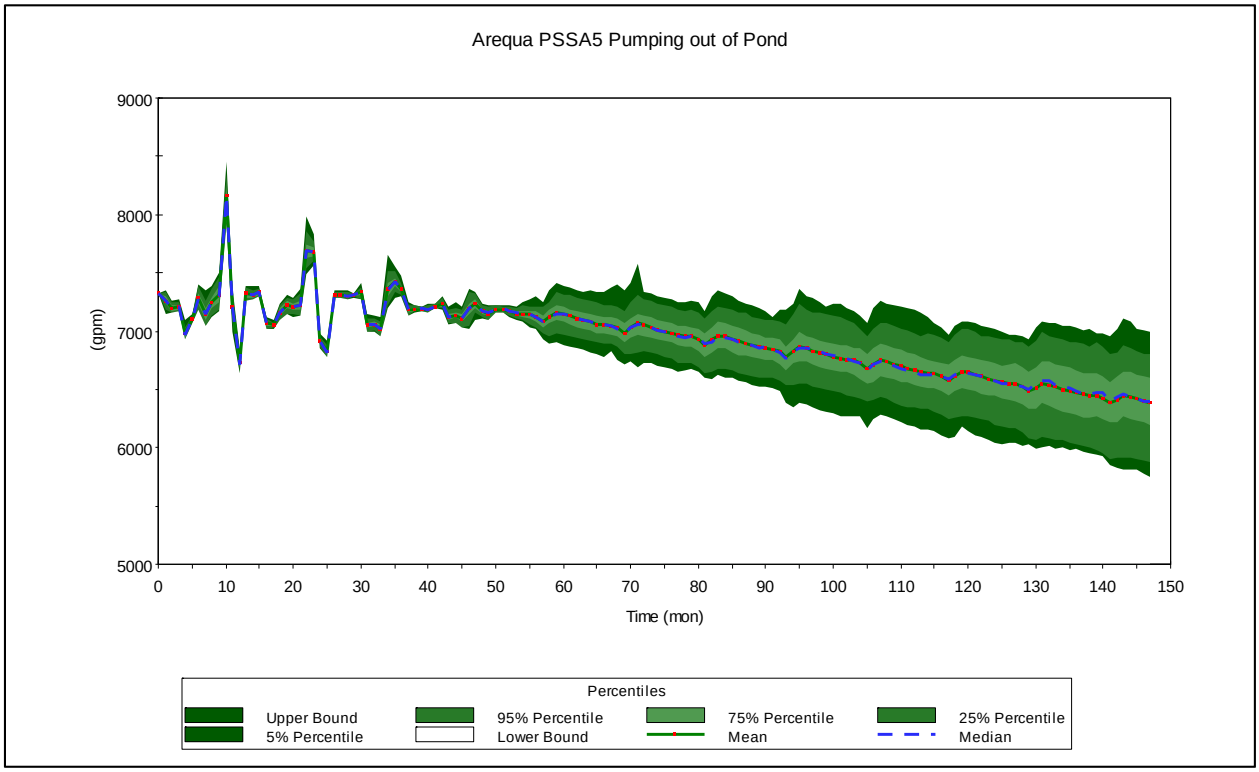
Figure 24 – Arequa Gulch PSSA5 Remaining Freeboard



Pumping from Arequa Gulch PSSA 5

The amount of solution predicted to be pumped from the PSSA for processing is presented in **Figure 25**. During operations when the amount of solution applied to the heap is 7,400 gpm, an average of approximately 7,300 gpm is expected to be available for pumping to the process facility. Once the facility switches to closure the pumping is expected to steadily decrease with a final value on the order of 6,600 gpm predicted after eight years.

Figure 25 – Arequa Gulch PSSA5 Pumping out of Pond



Combined Arequa Gulch Stochastic Results

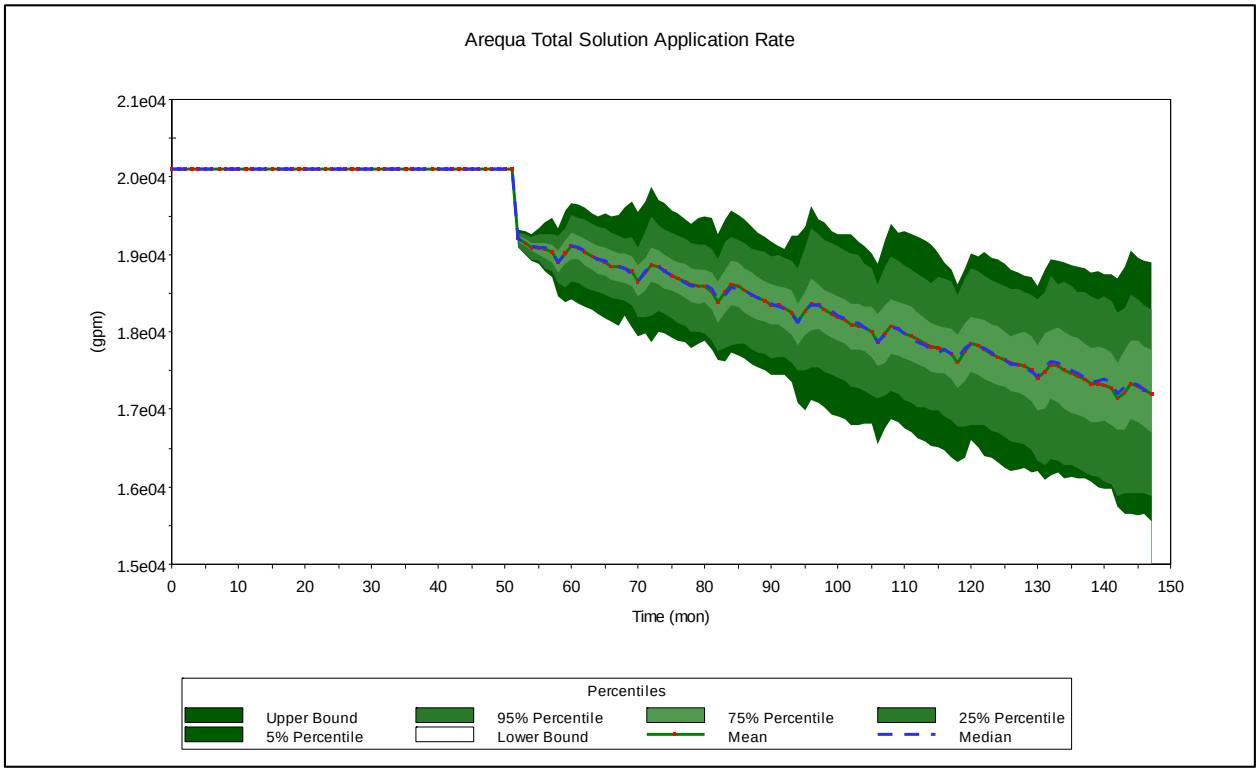
This section of the report presents results for the combined Arequa *Gulch* Phase 1 to Phase 5 system.

Solution Application

The total solution predicted to be applied to the top of the Arequa Gulch Phase 1 heap is presented in **Figure 26**. During operations, application is predicted to be maintained at the target rate of 20,100 until closure.

During closure the applied solution is predicted to decrease. Based on average precipitation conditions, over the 8-year closure period modeled the solution rate is predicted to decrease to roughly 17,700 gpm. Flows could be reduced even further if a greater portion of the heap were to be closed.

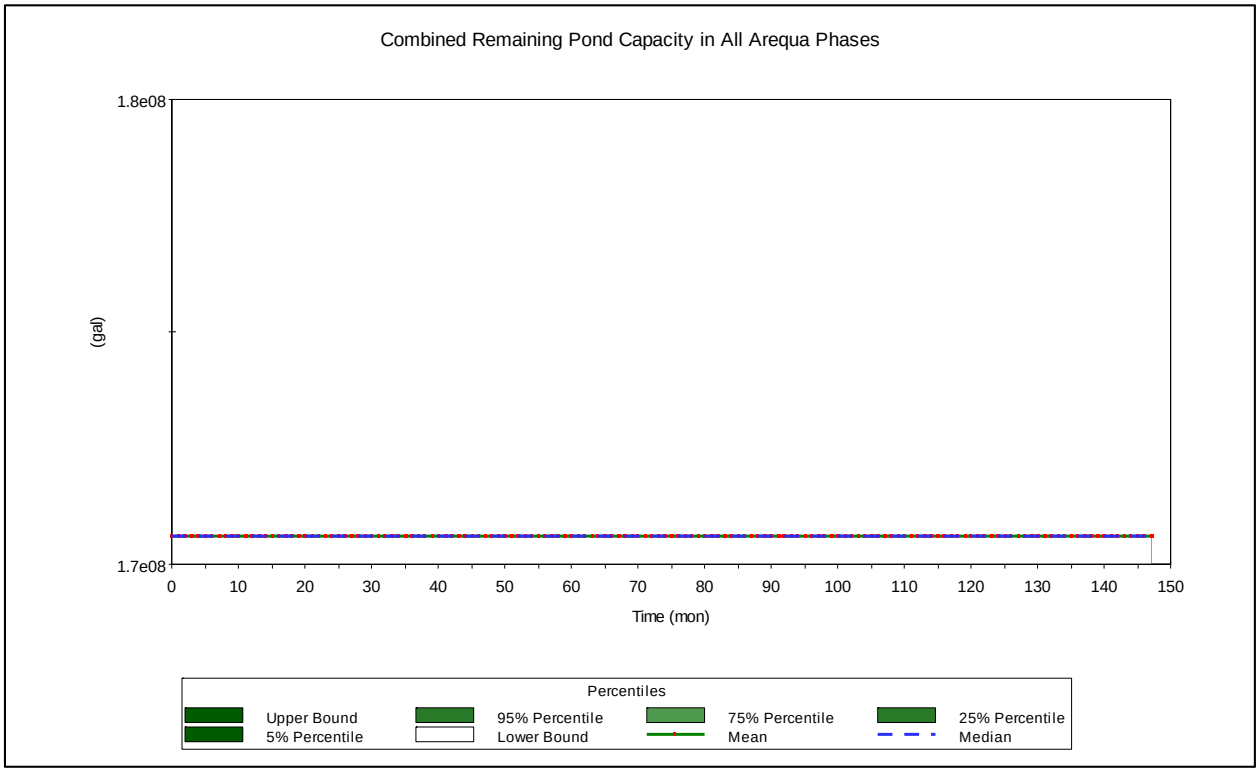
Figure 26 – Arequa Gulch Total Solution Application Rate



Remaining Pond Capacity

The total amount of pond capacity predicted to be available at each month of the simulation for the four ponds combined was calculated by the model. Results of this calculation are presented in **Figure 27**. Results show that at all times, the entire capacity of the four PSSAs will be available as net losses exceed net gains for all months (as shown in the monthly results above). 170.6 million gallons of excess storage capacity is predicted to exist during all months of the simulation.

Figure 27 – Combined Remaining Pond Capacity in All Arequa Gulch Phases



Makeup Water

Makeup water requirements were determined for the combined Arequa Gulch system. These results are provided in **Figure 28**. Results suggest that the total required makeup water will be somewhat variable and could range from no water in a given month to as high as approximately 1,500 gpm. On average, makeup water requirements are expected to be roughly 800-900 gpm. Makeup requirements will cease with active operations and be maintained at zero during the closure period.

Figure 28 – Arequa Gulch Total Makeup Water Requirements



Arequa Gulch VLF Results Considering 100-Year Runoff and Draindown Due to 12 Hours of Power Loss

As was done for the Squaw Valley VLF, a deterministic simulation was conducted on the Arequa Gulch site using mean monthly precipitation and the runoff from the 100-year, 24-hour event as well as the draindown caused by 12 hours of power loss. The purpose of this analysis was to determine whether this condition or conditions predicted by the stochastic model resulted in the more critical condition for pond storage.

Arequa Gulch Phase 1 Results

Estimated solution volume and pond freeboard in the Arequa Gulch Phase 1 PSSA are shown in **Figures 29** and **30**. The peak pond volume is approximately 14 million gallons and the minimum freeboard is about 25 feet. The sharp decline in pond volume and resulting increase in freeboard after month 51 is due to the mine entering closure conditions and decreased areas of surface runoff, although the pond freeboard only increases by about 4 feet over this period. These results are more critical than the stochastic results which predicted that the PSSA could be maintained at its minimum level throughout operations and closure.

Figure 29 – Arequa Gulch PSSA1 Pond Volume with 100-year, 24-hour Runoff and Draindown Due to Power Loss

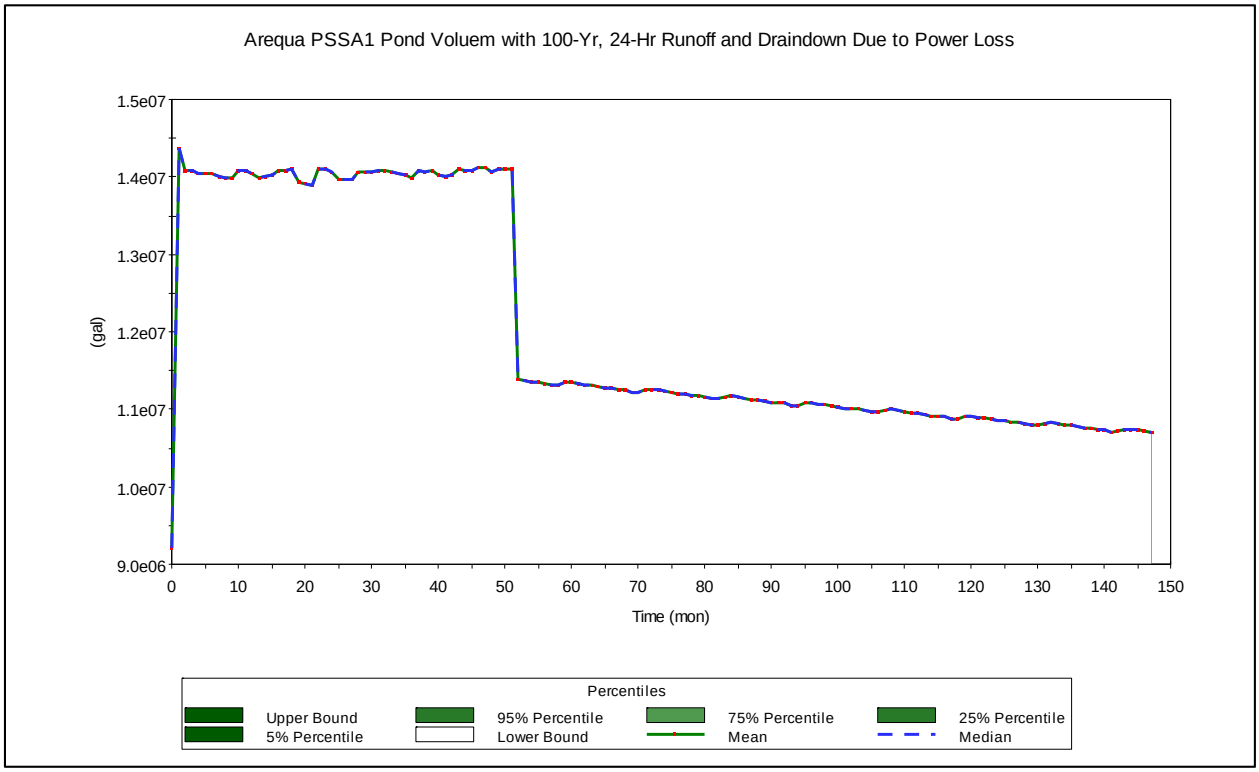
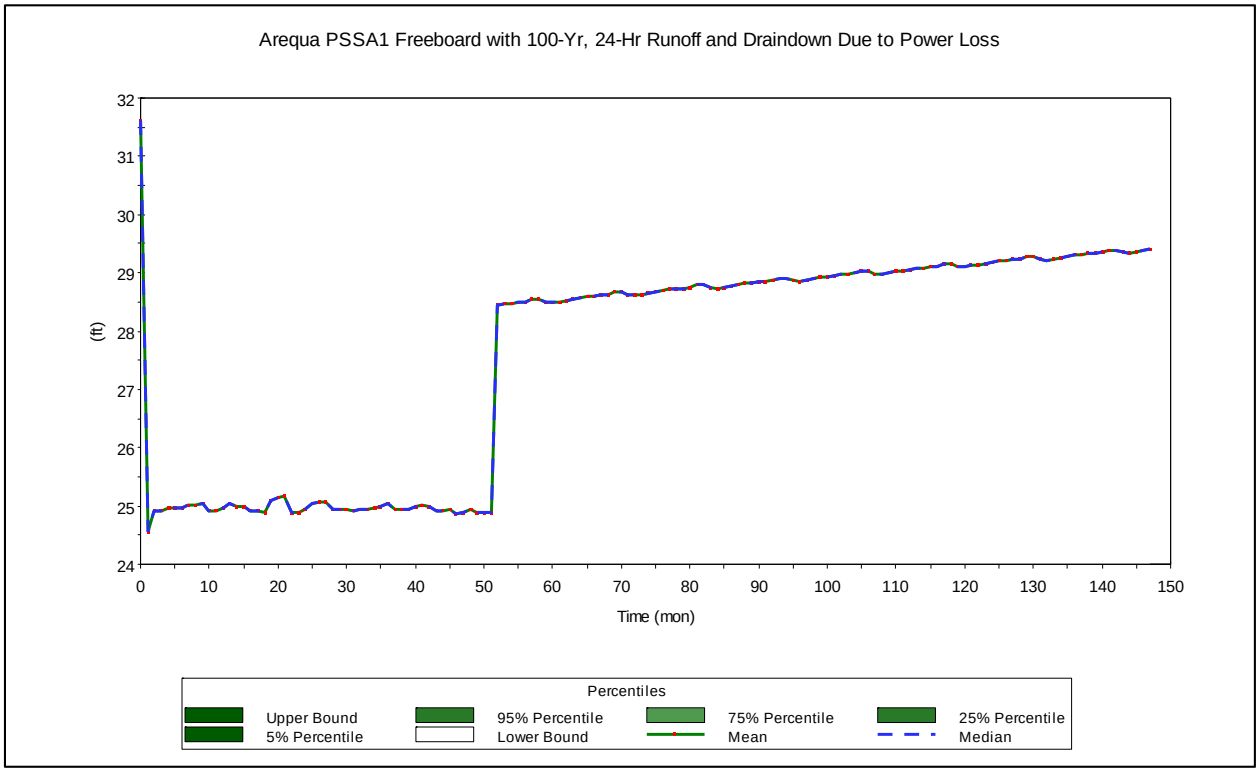


Figure 30 – Arequa Gulch PSSA1 Freeboard with 100-year, 24-hour Runoff and Draindown Due to Power Loss



Arequa Gulch Phase 2 Results

Estimated solution volume and pond freeboard in the Arequa Gulch Phase 2 PSSA are shown in **Figures 31** and **32**. The peak pond volume is about 13.5 million gallons and the minimum freeboard is about 20 feet. As in Phase 1, the pond volume decreases drastically when closure conditions begin. The pond freeboard increases by about 9 feet from month 46 through the end of the simulation. These results are more critical than the stochastic results which predicted that the PSSA could be maintained at its minimum level throughout operations and closure.

Figure 31 – Arequa Gulch PSSA2 Pond Volume with 100-year, 24-hour Runoff and Draindown Due to Power Loss

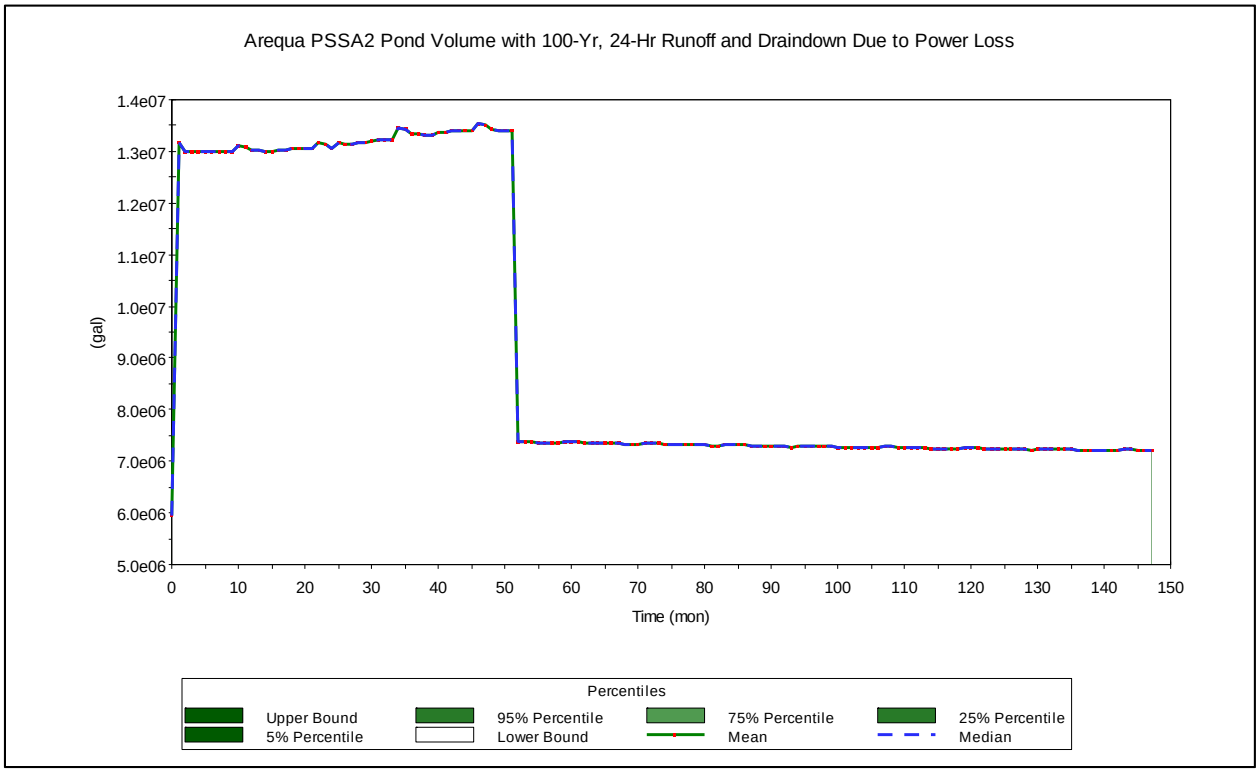
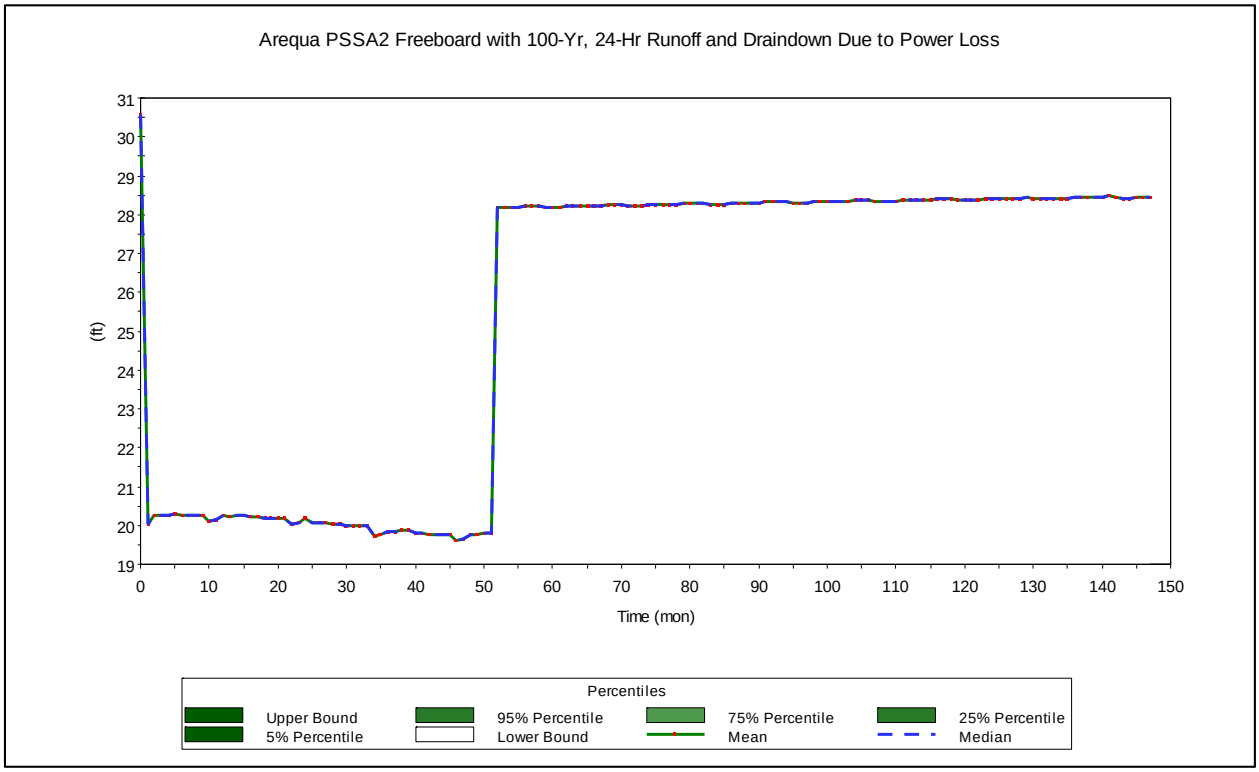


Figure 32 – Arequa Gulch PSSA2 Freeboard with 100-year, 24-hour Runoff and Draindown Due to Power Loss



Arequa Gulch Phase 4 Results

Estimated solution volume and pond freeboard in the Arequa Gulch Phase 4 PSSA are shown in **Figures 33** and **34**. The peak pond volume is about 14.5 million gallons and the minimum freeboard is about 33.5 feet. Phase 4 also demonstrates a decrease in pond volume after closure conditions begin, although the reduction is less pronounced in this phase than in Phases 1 or 2, with an increase in pond freeboard of only about 2.5 feet. These results are more critical than the stochastic results which predicted that the PSSA could be maintained at its minimum level throughout operations and closure.

Figure 33 – Arequa Gulch PSSA4 Pond Volume with 100-year, 24-hour Runoff and Draindown Due to Power Loss

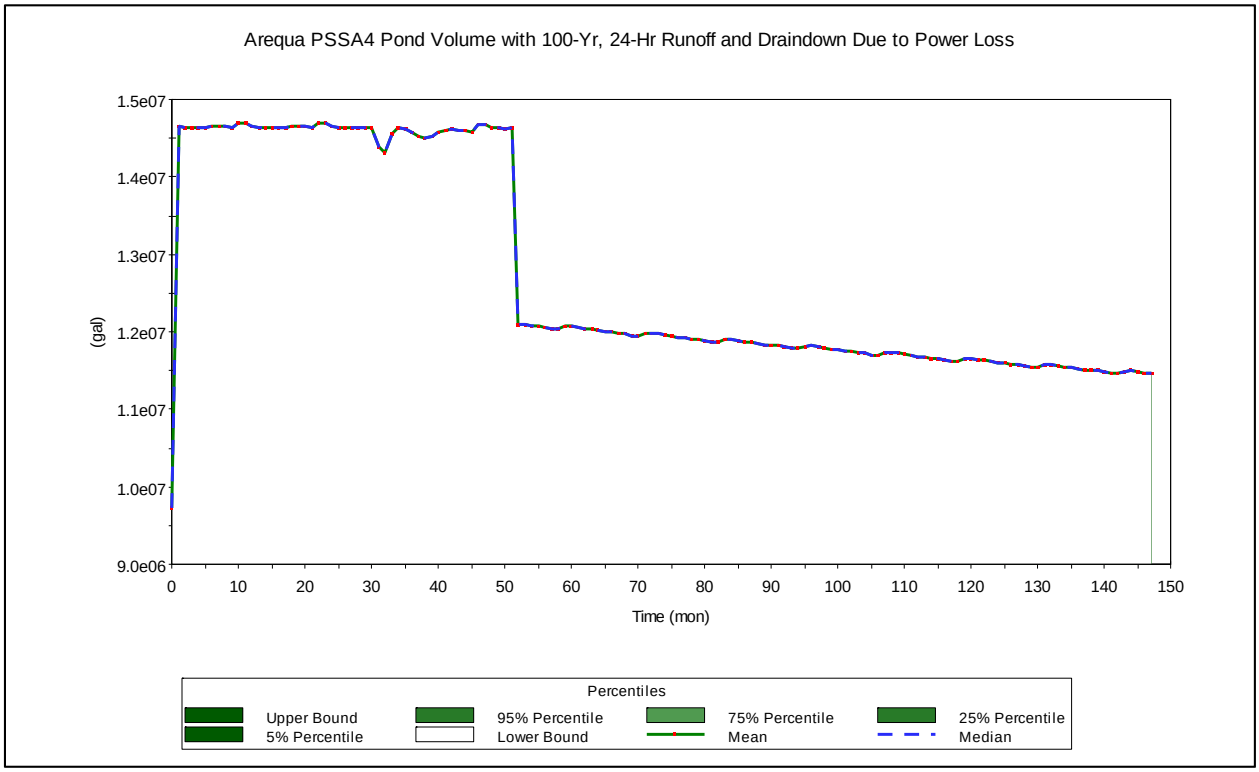
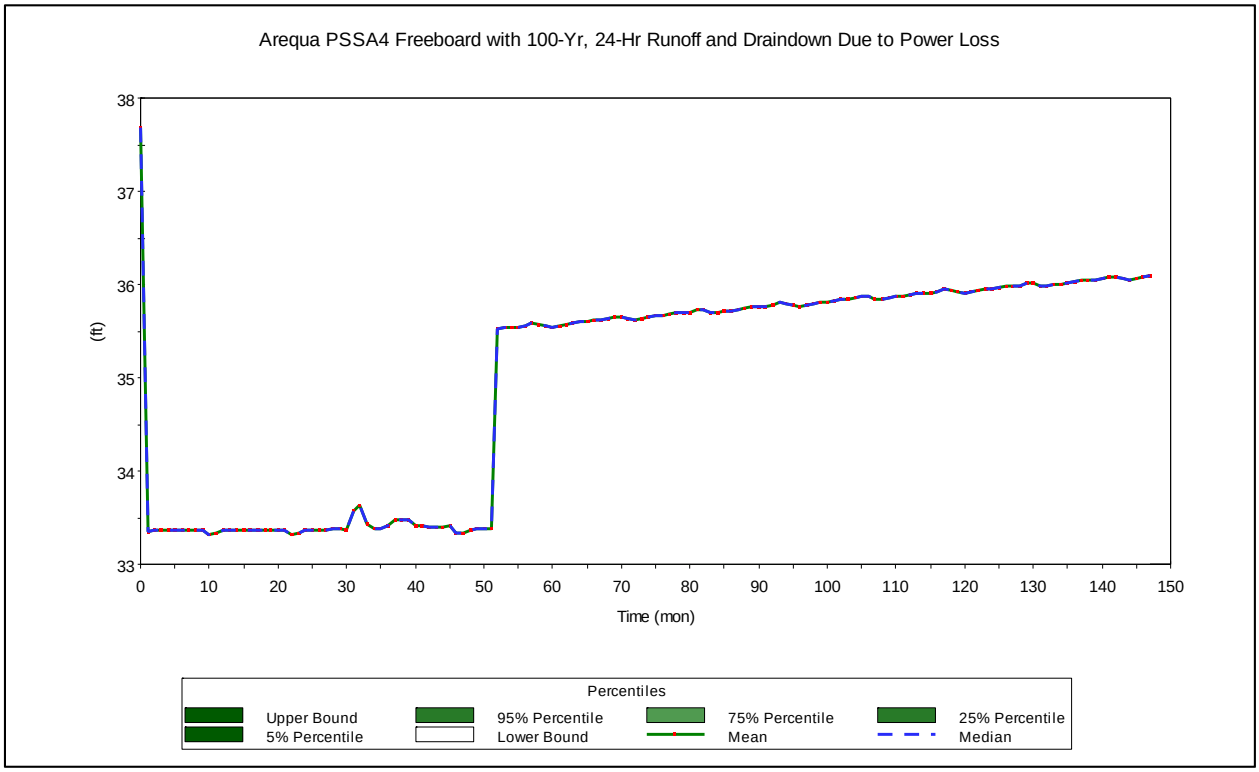


Figure 34 – Arequa Gulch PSSA4 Freeboard with 100-year, 24-hour Runoff and Draindown Due to Power Loss



Arequa Gulch Phase 5 Results

Estimated solution volume and pond freeboard in the Arequa Gulch Phase 5 PSSA are shown in **Figures 35** and **36**. The peak pond volume is about 12 million gallons and the minimum freeboard is about 27 feet. Phase 5 also demonstrates a decrease in pond volume after closure conditions begin. The increase in freeboard at this phase is on a similar scale of that seen in Phase 4, with an increase in pond freeboard of only about 2.5 feet. These results are more critical than the stochastic results which predicted that the PSSA could be maintained at its minimum level throughout operations and closure.

Figure 35 – Arequa Gulch PSSA5 Pond Volume with 100-year, 24-hour Runoff and Draindown Due to Power Loss

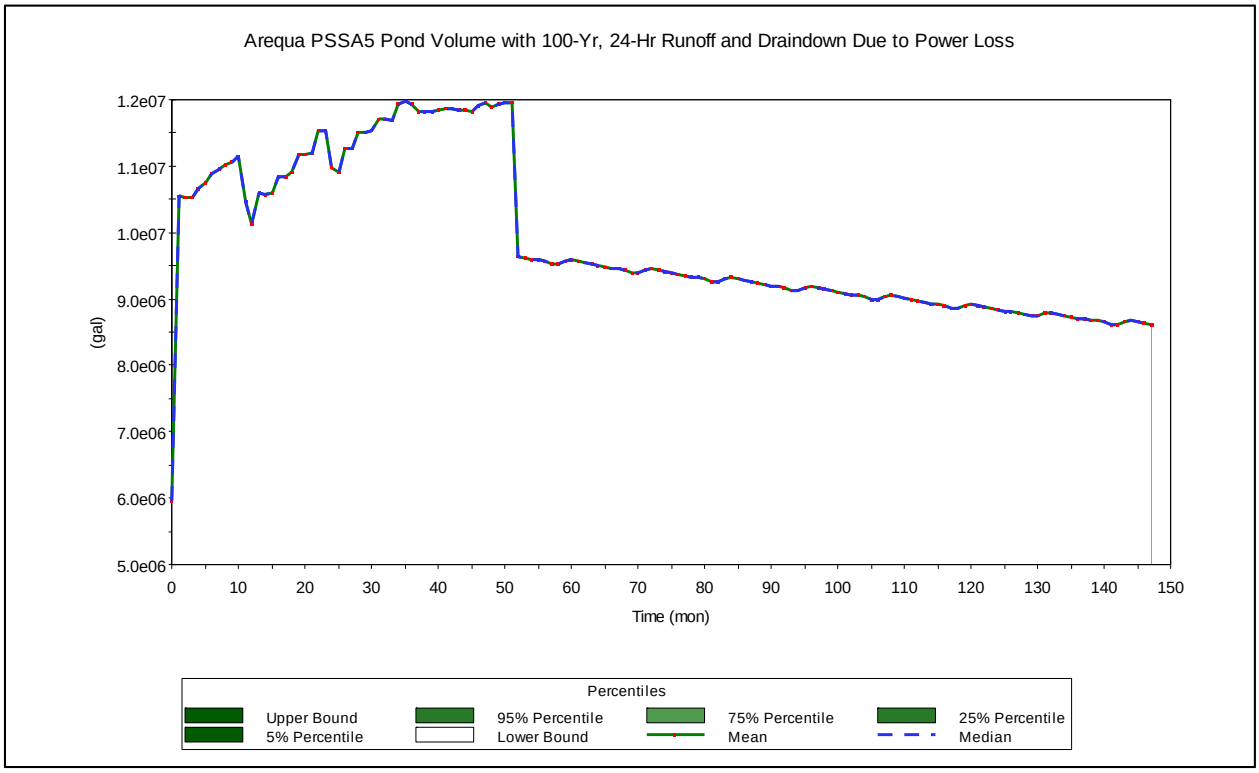
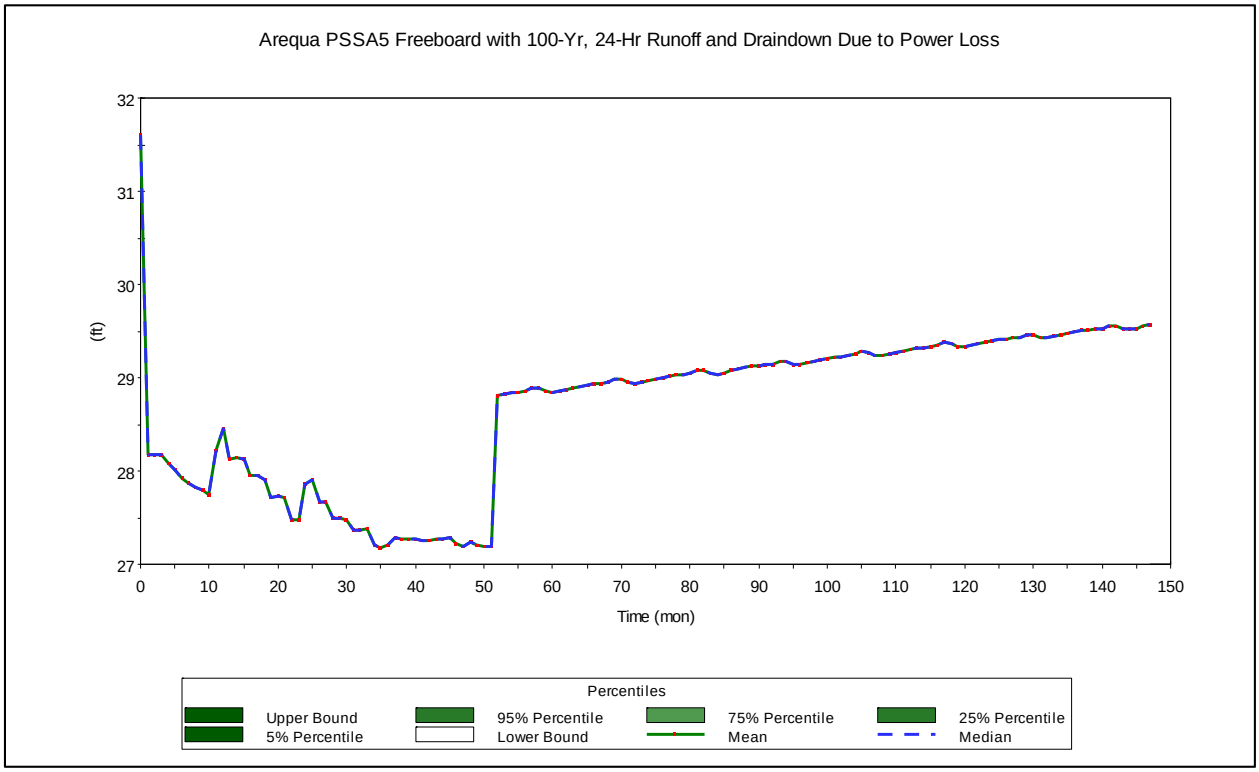


Figure 36 – Arequa Gulch PSSA5 Freeboard with 100-year, 24-hour Runoff and Draindown Due to Power Loss



Conclusions

A water balance model was completed to evaluated planned operations and closure for the Squaw Valley and Arequa Gulch leach facilities. The model was set up to evaluate Squaw Valley as a stand-alone system with the pad draining to a single PSSA. The Arequa Gulch site was modeled as four systems (Phase 1, Phase 2, Phase 4, and Phase 5) each reporting to a separate PSSAs, with all PSSAs linked to a single process facility. Required pond storage, makeup water and total flow rates were determined by the model.

Results indicate that the Squaw Valley PSSA is predicted to have sufficient capacity in its PSSA for all conditions. Given both average and upper bound precipitation, freeboard is likely to be maintained at its maximum value of approximately 18 feet or more throughout operations. Given average precipitation conditions plus the 100-year, 24-hour storm and a 12-hour draindown event due to power loss, the pond volume is expected to exceed its minimum level for all months. A minimum freeboard of approximately 75 feet was calculated during this simulation, with freeboard approaching 100 feet during closure conditions. Makeup water required for the Squaw Valley system will vary considerably throughout operations but in general are expected to be under 1,000 gpm in most months. A couple of individual spikes in makeup water are predicted; these spikes correspond to months when loading and leaching patterns will cause ore absorption to greatly exceed draindown. During closure the total amount of flow required to be recirculated to the pad is expected to decrease to roughly 13,000 gpm. This value could be reduced further if additional areas were closed and graded to drain away from the PSSA.

Results were developed for the individual Arequa Gulch PSSAs as well as the combined system. Individually the results suggest that all ponds can be maintained at their minimum amounts throughout all of operations while applying the target flow rates based on the stochastic model results. When looking at the four PSSAs as a combined system, the remaining PSSA capacity is predicted to be at a maximum value of 170.6 million gallons for all months and all stochastic precipitation conditions. This indicates that there is ample storage space for all anticipated solution. Pond volume was also evaluated assuming average precipitation conditions plus a 100-year, 24-hour event and 12-hours of draindown. In this situation pond volumes will exceed their minimum levels. Under these conditions, each of the Arequa Gulch PSSAs was calculated to have a freeboard of at least around 20 feet remaining in the ponds.

Required make up water for the combined Arequa Gulch system is expected to vary significantly but average approximately 800-900 gpm. No makeup water will be required during closure conditions. Over the 8-year closure period, the total amount of flow required to be recirculated to the pads is expected to decrease from 20,100 gpm to roughly 17,700 gpm. This value could be reduced further if additional areas were closed and graded to drain away from the PSSAs.

References

AMEC Earth & Environmental (AMEC). *Squaw Valley VLF Water Balance*. Job No. 1125G. August 2011.

Ecological Resource Consultants, Inc. (ERC). *Water Balance Analysis – Permitting Model*. Technical Memorandum. Evergreen, CO. March 2008.

Smith Williams Consultants, Inc. (SWC). *Cripple Creek & Victor Gold Mining Company, Cresson Project, Valley Leach Facility, Phase 5 Extension Design*. Project 1125. Appendix G. Englewood, CO. March 2008.

Appendices

Appendix A – Heap Geometry and Loading Data

Appendix B – PSSA Filling Curves

Appendix A

Heap Geometry and Loading Data

Appendix A.1

Squaw Valley VLF Data

		Lift Volume (yd^3)	Lift Volumes (tons)	Lift Capacity (days)	Cumulative Volume (yd^3)	Cumulative Volume (tons)	Top of Lift Elevation (ft)	Total surface Area of Lift (ft^2)	Flat Surface Area of Lift (ft^2)	Sloped Area of Lfit (ft^2)	Averge lift depth to liner (ft)	Total Surface Area of Heap (ft^2)	Flat Surface Area of Heap (ft^2)	Sloped Area of Heap (ft^2)	Total Exposed Liner Area (ft^2)	Average Heap Depth to Liner (ft)
2016	Q4	3,895,834	5,785,314	87	3,895,834	5,785,314	9,550	1,569,297	1,221,084	348,213	67	1,569,297	1,221,084	348,213	12,506,473	67
2017	Q1	3,837,767	5,699,085	86	7,733,602	11,484,399	9,550	1,470,490	1,357,118	113,372	103	2,213,100	1,908,052	305,048	11,862,670	94
	Q2	3,869,316	5,745,934	86	11,602,918	17,230,333	9,650	1,682,003	1,291,456	390,547	130	2,835,900	2,253,675	582,225	11,239,869	110
	Q3	3,810,272	5,658,254	85	15,413,190	22,888,587	9,650	1,644,674	1,288,059	356,616	120	3,490,463	2,790,414	700,049	10,585,307	119
	Q4	3,844,469	5,709,037	86	19,257,659	28,597,624	9,750	2,050,238	1,821,404	228,834	64	4,919,417	4,220,696	698,721	9,156,353	105
2018	Q1	3,933,678	5,841,511	88	23,191,337	34,439,135	9,750	1,436,816	832,683	604,132	230	4,919,417	3,765,373	1,154,044	9,156,353	127
	Q2	3,563,785	5,292,221	80	26,755,122	39,731,356	9,750	1,578,736	1,462,516	116,220	100	5,691,946	4,589,181	1,102,765	8,383,823	126
	Q3	3,929,719	5,835,633	88	30,684,841	45,566,989	9,750	1,503,857	1,218,386	285,471	161	6,012,401	4,941,297	1,071,104	8,063,369	137
	Q4	3,414,136	5,069,992	76	34,098,976	50,636,980	9,750	1,624,819	1,610,322	14,497	80	7,022,855	6,096,167	926,689	7,052,914	131
2019	Q1	4,176,462	6,202,046	93	38,275,438	56,839,026	9,850	1,566,495	1,188,764	377,731	106	7,626,035	6,321,562	1,304,473	6,449,734	135
	Q2	3,826,193	5,681,896	85	42,101,631	62,520,922	9,850	1,438,642	1,128,152	310,490	175	7,891,084	6,493,281	1,397,803	6,184,685	143
	Q3	3,835,831	5,696,208	86	45,937,461	68,217,130	9,850	1,465,453	1,061,544	403,909	250	8,084,234	6,535,535	1,548,698	5,991,536	153
	Q4	3,869,957	5,746,887	86	49,807,419	73,964,017	9,850	1,421,191	1,069,138	352,053	221	8,257,886	6,564,547	1,693,339	5,817,884	162
2020	Q1	4,147,434	6,158,940	93	53,954,853	80,122,956	9,850	1,393,650	1,061,694	331,956	159	8,549,308	6,683,530	1,865,777	5,526,462	170
	Q2	3,632,367	5,394,066	81	57,587,220	85,517,022	9,950	1,679,896	1,183,086	496,810	150	9,008,599	6,848,956	2,159,643	5,067,171	173
	Q3	3,935,251	5,843,847	88	61,522,471	91,360,869	9,950	1,527,542	1,300,681	226,861	131	9,548,664	7,309,233	2,239,432	4,527,105	174
	Q4	2,844,439	4,223,992	64	64,366,910	95,584,862	9,950	1,404,544	1,084,066	320,478	227	9,681,477	7,407,584	2,273,893	4,394,293	182
2021	Q1	4,798,986	7,126,494	107	69,165,896	102,711,356	9,950	1,385,784	1,092,981	292,803	270	9,888,225	7,537,915	2,350,310	4,187,545	189
	Q2	3,824,989	5,680,109	85	72,990,886	108,391,465	9,950	1,470,070	1,067,124	402,946	224	10,150,277	7,602,862	2,547,415	3,925,492	194
	Q3	3,802,286	5,646,394	85	76,793,171	114,037,859	9,950	1,413,616	1,135,075	278,541	191	10,396,478	7,822,259	2,574,219	3,679,292	199
	Q4	3,932,825	5,840,245	88	80,725,996	119,878,104	10,050	1,619,580	1,233,527	386,052	106	11,075,872	8,268,240	2,807,632	2,999,898	197
2022	Q1	3,900,369	5,792,047	87	84,626,365	125,670,152	10,050	1,447,032	947,121	499,911	227	11,159,758	8,081,063	3,078,696	2,916,012	205
	Q2	3,934,871	5,843,284	88	88,561,236	131,513,436	10,050	1,421,347	1,111,147	310,200	301	11,306,176	8,184,169	3,122,006	2,769,594	211
	Q3	3,866,657	5,741,986	86	92,427,893	137,255,422	10,050	1,422,143	1,130,021	292,122	276	11,545,430	8,354,793	3,190,636	2,530,340	216
	Q4	3,791,340	5,630,140	85	96,219,233	142,885,561	10,050	1,418,652	1,056,350	362,302	250	11,789,575	8,429,284	3,360,291	2,286,195	220
2023	Q1	3,890,137	5,776,853	87	100,109,370	148,662,414	10,050	1,438,735	1,136,777	301,958	249	11,998,708	8,614,191	3,384,517	2,077,062	225
	Q2	3,831,775	5,690,186	86	103,941,145	154,352,600	10,150	1,521,357	1,031,655	489,702	162	12,313,646	8,638,876	3,674,769	1,762,124	228
	Q3	3,899,840	5,791,262	87	107,840,985	160,143,862	10,150	1,416,448	907,838	508,610	255	12,400,852	8,350,752	4,050,101	1,674,917	235
	Q4	3,832,106	5,690,677	86	111,673,090	165,834,539	10,150	1,383,868	1,074,135	309,733	331	12,528,678	8,432,324	4,096,354	1,547,092	241
2024	Q1	3,823,164	5,677,399	85	115,496,255	171,511,938	10,150	1,390,601	1,088,550	302,051	294	12,718,107	8,548,110	4,169,997	1,357,663	245
	Q2	3,937,541	5,847,248	88	119,433,796	177,359,187	10,150	1,460,256	1,096,563	363,693	260	12,955,973	8,630,118	4,325,855	1,119,797	249
	Q3	3,818,329	5,670,218	85	123,252,124	183,029,405	10,150	1,398,326	1,023,218	375,108	299	13,079,748	8,653,877	4,425,871	996,022	254
	Q4	3,611,300	5,362,781	81	126,863,425	188,392,186	10,150	1,283,252	921,054	362,199	280	13,114,346	8,582,998	4,531,347	961,424	261
2025	Q1	3,911,281	5,808,253	87	130,774,706	194,200,438	10,250	1,372,139	761,363	610,776	327	13,114,346	7,811,753	5,302,593	961,424	269
	Q2	3,759,086	5,582,243	84	134,533,792	199,782,681	10,250	1,321,557	934,888	386,669	396	13,114,346	7,972,222	5,142,124	961,424	277
	Q3	3,931,989	5,839,004	88	138,465,781	205,621,685	10,250	1,371,871	939,122	432,749	316	13,114,346	7,562,026	5,552,319	961,424	285
	Q4	3,870,190	5,747,232	86	142,335,971	211,368,917	10,250	1,360,551	935,162	425,389	315	13,114,346	7,346,793	5,767,553	961,424	293
2026	Q1	3,727,137	5,534,799	83	146,063,108	216,903,716	10,350	1,405,976	868,538	537,428	381	13,114,346	7,043,192	6,071,154	961,424	301
	Q2	3,876,582	5,756,724	87	149,939,690	222,660,440	10,350	1,331,420	823,776	507,645	483	13,114,346	6,598,018	6,516,327	961,424	309
	Q3	3,875,145	5,754,591	87	153,814,835	228,415,031	10,350	1,350,923	875,792	475,131	407	13,114,346	6,252,742	6,861,603	961,424	317
	Q4	3,990,901	5,926,488	89	157,805,736	234,341,518	10,350	1,358,086	952,506	405,580	476	13,114,346	6,007,741	7,106,604	961,424	325
2027	Q1	3,821,130	5,674,379	85	161,626,867	240,015,897	10,450	1,398,900	693,274	705,626	530	13,114,346	5,302,115	7,812,230	961,424	333
	Q2	2,541,192	3,773,671	57	164,168,059	243,789,568	10,450	910,531	546,096	364,435	555	13,114,346	5,026,830	8,087,516	961,424	338

Appendix A.2

Arequa Gulch VLF Data

Comments	Current Lift Min Elevation (ft)	Current Lift Max Elevation (ft)	Incremental Capacity (yd^3)	Incremental Capacity (tons)	Incremental Capacity (days)	Cumulative Capacity (yd^3)	Cumulative Capacity (tons)	Ore to be Leached: Total Flat Leach Area (ft^2)	Ore to be Leached: Total Sloped Leach Area (ft^2)
Existing Condition	-	-	0	0	0	196,649,650	292,024,730	-	-
EOY 2011	9,920	9,970	4,166,906	6,187,856	93	200,816,556	298,212,586	1,890,827	412,693
STACKING-20120301	9,970	10,020	4,105,780	6,097,084	92	204,922,337	304,309,670	2,232,712	401,665
STACKING-20120601	10,020	10,070	3,996,816	5,935,272	89	208,919,153	310,244,942	2,224,029	315,171
STACKING-20120901	10,070	10,070	3,951,450	5,867,904	88	212,870,603	316,112,845	2,064,924	343,071
STACKING-20130101	10,070	10,120	3,954,270	5,872,091	88	216,824,873	321,984,936	2,533,917	454,279
STACKING-20130301	10,070	10,120	4,093,770	6,079,248	91	220,918,642	328,064,184	2,115,021	389,687
STACKING-20130601	10,120	10,170	4,092,166	6,076,867	91	225,010,808	334,141,050	2,231,175	385,120
STACKING-20130901	10,170	10,170	3,841,916	5,705,246	86	228,852,725	339,846,296	1,983,516	454,357
STACKING-20140101	10,170	10,170	4,266,636	6,335,955	95	233,119,361	346,182,251	2,156,344	538,345
STACKING-20140301	10,140	10,220	3,954,883	5,873,001	88	237,074,244	352,055,252	2,147,936	778,281
STACKING-20140601	10,220	10,220	4,127,876	6,129,896	92	241,202,120	358,185,148	2,162,171	403,537
STACKING-20140901	10,220	10,220	3,703,745	5,500,062	83	244,905,865	363,685,209	1,836,939	518,478
STACKING-20150101	10,190	10,270	4,277,893	6,352,671	96	249,183,758	370,037,880	2,023,677	724,765
STACKING-20150301	10,270	10,270	4,185,051	6,214,801	93	253,368,809	376,252,681	2,094,552	490,760
STACKING-20150601	10,240	10,320	4,195,753	6,230,693	94	257,564,562	382,483,374	1,886,007	871,769
STACKING-20150901	10,320	10,370	4,222,638	6,270,617	94	261,787,199	388,753,991	1,756,675	750,798
STACKING-20160101	10,370	10,470	3,008,773	4,468,028	67	264,795,973	393,222,019	597,375	795,691

	Phase 1								
Comments	Lift Volume (cy)	Lift Volume (tons)	Total Flat Area (ft2)	Total Slope Area (ft2)	Flat Leach Area (ft2)	Sloped Leach Area (ft2)	Average Heap Height Under Leach (ft)	Total Ore Volume (cy)	Average Heap Depth (ft)
Existing Condition			-	-	-	-	-		0
EOY 2011	336,705	500,007	2,093,801	3,156,845	242,948	38,327	316	73,137,889	376
STACKING-20120301	955,431	1,418,816	2,254,546	2,996,100	609,943	75,739	379	74,116,265	381
STACKING-20120601	1,698,973	2,522,975	2,318,706	2,931,940	954,670	133,095	438	75,822,690	390
STACKING-20120901	547,051	812,371	2,336,626	2,914,020	302,836	60,488	450	76,368,875	393
STACKING-20130101	2,501,452	3,714,656	2,219,900	3,030,746	1,472,100	265,031	559	78,873,030	406
STACKING-20130301	581,514	863,548	2,194,198	3,056,448	299,139	59,025	460	79,454,544	409
STACKING-20130601	1,970,003	2,925,454	2,223,194	3,027,452	1,079,464	133,062	593	81,424,547	419
STACKING-20130901	523,350	777,175	2,078,981	3,171,665	218,041	144,213	510	81,947,898	421
STACKING-20140101	2,555,620	3,795,096	1,993,079	3,257,567	1,334,055	212,715	624	84,505,694	435
STACKING-20140301	183,526	272,536	2,016,596	3,234,050	110,970	34,208	550	84,689,221	435
STACKING-20140601	34,940	51,886	1,962,132	3,288,514	4,520	54,587	510	84,724,161	436
STACKING-20140901	2,713,811	4,030,009	1,787,186	3,463,460	1,368,690	229,411	649	87,437,972	450
STACKING-20150101	0	0	1,787,186	3,463,460	0	0	0	87,437,972	450
STACKING-20150301	1,920,447	2,851,864	1,534,254	3,716,392	907,868	252,932	685	89,358,419	460
STACKING-20150601	251,709	373,788	1,523,831	3,726,815	130,706	76,106	755	89,610,128	461
STACKING-20150901	1,305,383	1,938,493	1,255,504	3,995,142	578,711	268,296	727	90,915,511	468
STACKING-20160101	527,201	782,894	1,106,359	4,144,287	141,581	157,028	743	91,442,712	470

Comments	Phase 2								
	Lift Volume (cy)	Lift Volume (tons)	Total Flat Area (ft2)	Total Slope Area (ft2)	Flat Leach Area (ft2)	Sloped Leach Area (ft2)	Average Heap Height Under Leach (ft)	Total Ore Volume (cy)	Average Heap Depth (ft)
Existing Condition			-	-	-	-	-		0
EOY 2011	0	0	1,216,453	3,935,118	0	0	0	67,378,428	353
STACKING-20120301	0	0	1,216,453	3,935,118	0	0	0	68,115,042	357
STACKING-20120601	143,820	213,572	1,218,644	3,932,927	109,325	28,853	458	68,115,042	357
STACKING-20120901	0	0	1,218,644	3,932,927	0	0	0	68,115,042	357
STACKING-20130101	591,684	878,651	1,144,452	4,007,119	591,981	116,073	612	68,115,042	357
STACKING-20130301	0	0	1,144,452	4,007,119	0	0	0	68,115,042	357
STACKING-20130601	0	0	1,144,452	4,007,119	0	0	0	68,115,042	357
STACKING-20130901	0	0	1,144,452	4,007,119	0	0	0	68,115,042	357
STACKING-20140101	753,354	1,118,731	934,125	4,217,445	281,309	262,431	670	68,115,042	357
STACKING-20140301	495,912	736,430	906,906	4,244,665	236,913	209,975	636	69,364,683	364
STACKING-20140601	0	0	906,906	4,244,665	0	0	0	69,364,683	364
STACKING-20140901	551,901	819,572	725,413	4,426,158	204,271	220,480	696	69,916,568	366
STACKING-20150101	8,652	12,848	714,020	4,437,550	14,509	11,392	643	69,925,219	366
STACKING-20150301	162,425	241,201	652,899	4,498,671	73,415	62,326	711	70,087,644	367
STACKING-20150601	0	0	652,899	4,498,671	0	0	0	70,087,644	367
STACKING-20150901	42,184	62,643	624,346	4,527,224	9,973	28,553	746	70,129,828	368
STACKING-20160101	0	0	624,346	4,527,224	0	0	0	70,129,828	368

Comments	Phase 4								
	Lift Volume (cy)	Lift Volume (tons)	Total Flat Area (ft2)	Total Slope Area (ft2)	Flat Leach Area (ft2)	Sloped Leach Area (ft2)	Average Heap Height Under Leach (ft)	Total Ore Volume (cy)	Average Heap Depth (ft)
Existing Condition			-	-	-	-	-		0
EOY 2011	0	0	1,873,737	2,954,955	0	0	0	44,638,278	250
STACKING-20120301	0	0	1,873,737	2,954,955	0	0	0	44,638,278	250
STACKING-20120601	0	0	1,873,737	2,954,955	0	0	0	44,638,278	250
STACKING-20120901	0	0	1,873,737	2,954,955	0	0	0	44,638,278	250
STACKING-20130101	0	0	1,873,737	2,954,955	0	0	0	44,638,278	250
STACKING-20130301	0	0	1,873,737	2,954,955	0	0	0	44,638,278	250
STACKING-20130601	0	0	1,873,737	2,954,955	0	0	0	44,638,278	250
STACKING-20130901	0	0	1,873,737	2,954,955	0	0	0	44,638,278	250
STACKING-20140101	0	0	1,873,737	2,954,955	0	0	0	44,638,278	250
STACKING-20140301	2,364,406	3,511,142	1,640,454	3,188,238	1,359,561	308,106	406	47,008,197	263
STACKING-20140601	0	0	1,640,454	3,188,238	0	0	0	47,008,197	263
STACKING-20140901	0	0	1,640,454	3,188,238	0	0	0	47,008,197	263
STACKING-20150101	1,806,945	2,683,314	1,296,911	3,531,781	837,766	342,693	463	48,815,142	273
STACKING-20150301	0	0	1,296,911	3,531,781	0	0	0	48,815,142	273
STACKING-20150601	851,540	1,264,537	978,769	3,849,923	321,847	315,629	512	49,666,682	278
STACKING-20150901	0	0	978,769	3,849,923	0	0	0	49,666,682	278
STACKING-20160101	0	0	978,769	3,849,923	0	0	0	49,666,682	278

Comments	Phase 5								
	Lift Volume (cy)	Lift Volume (tons)	Total Flat Area (ft2)	Total Slope Area (ft2)	Flat Leach Area (ft2)	Sloped Leach Area (ft2)	Average Heap Height Under Leach (ft)	Total Ore Volume (cy)	Average Heap Depth (ft)
Existing Condition			-	-	-	-	-		0
EOY 2011	3,830,201	5,687,849	2,228,143	1,008,562	1,647,879	374,366	129	15,371,061	72
STACKING-20120301	3,150,349	4,678,268	2,356,100	1,198,621	1,622,769	325,800	162	18,510,279	86
STACKING-20120601	2,154,023	3,198,724	2,465,046	1,254,807	1,160,034	153,224	186	20,655,536	96
STACKING-20120901	3,404,399	5,055,532	2,586,756	1,467,307	1,762,088	282,583	181	24,033,573	112
STACKING-20130101	861,134	1,278,784	2,632,748	1,469,346	469,836	73,149	217	24,904,863	116
STACKING-20130301	3,512,255	5,215,699	2,812,417	1,760,989	1,815,881	330,654	193	28,492,242	133
STACKING-20130601	2,122,163	3,151,412	2,931,875	1,885,967	1,151,711	251,935	169	30,598,807	142
STACKING-20130901	3,318,566	4,928,070	3,032,321	2,096,659	1,765,476	310,068	205	33,898,538	158
STACKING-20140101	957,662	1,422,128	3,079,517	2,049,463	540,981	63,199	328	34,841,585	162
STACKING-20140301	911,039	1,352,893	3,140,788	2,255,850	440,492	224,395	86	35,749,000	166
STACKING-20140601	4,092,936	6,078,010	3,372,356	2,431,182	2,159,710	346,890	218	39,899,501	186
STACKING-20140901	438,034	650,480	3,403,823	2,399,715	264,074	68,469	421	40,337,535	188
STACKING-20150101	2,462,296	3,656,509	3,032,144	2,771,393	1,169,553	371,678	160	42,799,830	199
STACKING-20150301	2,102,179	3,121,736	2,947,310	2,856,227	1,113,269	175,208	387	44,902,009	209
STACKING-20150601	3,092,504	4,592,368	2,469,790	3,333,748	1,433,455	477,520	299	47,979,589	223
STACKING-20150901	2,875,071	4,269,480	2,131,384	3,672,154	1,166,420	455,490	388	50,869,584	237
STACKING-20160101	2,481,572	3,685,134	1,538,642	4,264,896	455,794	638,336	463	53,351,156	248

Comments	Phase 1		Phase 2		Phase 4		Phase 5	
	Total Liner Area (ft2)	Exposed Liner Area (ft2)	Total Liner Area (ft2)	Exposed Liner Area (ft2)	Total Liner Area (ft2)	Exposed Liner Area (ft2)	Total Liner Area (ft2)	Exposed Liner Area (ft2)
Existing Condition	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	3,242,572
EOY 2011	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	3,242,572
STACKING-20120301	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	2,566,834
STACKING-20120601	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	2,248,817
STACKING-20120901	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	2,083,684
STACKING-20130101	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	1,749,474
STACKING-20130301	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	1,701,444
STACKING-20130601	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	1,230,132
STACKING-20130901	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	985,067
STACKING-20140101	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	674,558
STACKING-20140301	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	674,558
STACKING-20140601	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	410,265
STACKING-20140901	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	0
STACKING-20150101	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	0
STACKING-20150301	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	0
STACKING-20150601	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	0
STACKING-20150901	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	0
STACKING-20160101	5,250,646	0	5,151,572	0	4,828,692	0	5,803,538	0

Appendix B

PSSA Filling Curves

Table B.1 – Squaw Valley PSSA Filling Curve

Elevation	Storage Volume (gal)
9,340	0
9,345	1,445,073
9,350	4,366,710
9,355	7,798,912
9,360	11,758,745
9,365	16,262,098
9,370	21,325,087
9,375	26,964,246
9,380	33,195,822
9,385	40,035,106
9,390	47,497,296
9,395	55,598,525
9,400	64,354,482
9,405	73,780,806
9,410	83,893,723
9,415	94,709,475
9,420	106,244,118
9,425	118,513,594
9,430	131,533,985
9,435	145,321,681
9,440	159,892,858
9,445	175,262,521
9,450	191,444,833

Table B.2 – Arequa Gulch PSSA 1 Filling Curve

Elevation	Storage Volume (gal)
9,298	0
9,299	11,331
9,300	26,661
9,301	46,717
9,302	72,226
9,303	103,916
9,304	143,361
9,305	192,623
9,306	253,275
9,307	326,895
9,308	414,996
9,309	517,639
9,310	634,643
9,311	767,158
9,312	916,275
9,313	1,083,146
9,314	1,267,953
9,315	1,470,876
9,316	1,693,007
9,317	1,935,436
9,318	2,199,315
9,319	2,484,220
9,320	2,789,968
9,321	3,117,954
9,322	3,469,631
9,323	3,846,454
9,324	4,247,393
9,325	4,671,417
9,326	5,119,799
9,327	5,593,873
9,328	6,094,910
9,329	6,621,335
9,330	7,171,088
9,331	7,744,835
9,332	8,343,365
9,333	8,967,344
9,334	9,615,559
9,335	10,286,981

9,336	10,982,459
9,337	11,702,779
9,338	12,448,790
9,339	13,219,947
9,340	14,015,523
9,341	14,836,063
9,342	15,682,233
9,343	16,554,639
9,344	17,453,161
9,345	18,377,677
9,346	19,328,914
9,347	20,307,660
9,348	21,314,582
9,349	22,349,375
9,350	23,411,678
9,351	24,502,216
9,352	25,621,779
9,353	26,771,092
9,354	27,949,852
9,355	29,157,758
9,356	30,395,596
9,357	31,664,094
9,358	32,963,979
9,359	34,295,493
9,360	35,658,817
9,361	37,054,680
9,362	38,483,808
9,363	39,946,988
9,364	41,452,220
9,365	43,007,864

Table B.3 – Arequa Gulch PSSA 2 Filling Curve

Elevation	Storage Volume (gal)
9,248	0
9,249	11,117
9,250	27,145
9,251	48,926
9,252	77,235
9,253	112,912
9,254	161,579
9,255	233,256
9,256	335,309
9,257	475,108
9,258	659,954
9,259	882,933
9,260	1,133,511
9,261	1,413,624
9,262	1,725,278
9,263	2,070,476
9,264	2,444,241
9,265	2,840,950
9,266	3,261,638
9,267	3,707,338
9,268	4,179,085
9,269	4,674,551
9,270	5,191,088
9,271	5,729,470
9,272	6,290,408
9,273	6,874,614
9,274	7,481,635
9,275	8,111,148
9,276	8,764,057
9,277	9,441,268
9,278	10,143,685
9,279	10,871,050
9,280	11,623,492
9,281	12,402,562
9,282	13,209,877
9,283	14,046,922
9,284	14,911,758
9,285	15,802,771

9,286	16,722,157
9,287	17,672,049
9,288	18,654,580
9,289	19,666,324
9,290	20,703,,663
9,291	21,768,147
9,292	22,861,327
9,293	23,984,820
9,294	25,136,621
9,295	26,314,469
9,296	27,519,591
9,297	28,753,022
9,298	30,015,990
9,299	31,307,848
9,300	32,627,627
9,301	33,975,909
9,302	35,353,275

Table B.4 – Arequa Gulch PSSA 4 Filling Curve

Elevation	Storage Volume (gal)
9,560	0
9,561	16,879
9,562	36,008
9,563	64,251
9,564	96,407
9,565	135,278
9,566	183,081
9,567	245,423
9,568	328,154
9,569	437,190
9,570	578,875
9,571	767,932
9,572	980,890
9,573	1,225,019
9,574	1,507,526
9,575	1,835,927
9,576	2,231,166
9,577	2,663,243
9,578	3,145,340
9,579	3,690,642
9,580	4,312,269
9,581	4,997,961
9,582	5,734,353
9,583	6,533,393
9,584	7,407,034
9,585	8,367,225
9,586	9,393,208
9,587	10,456,522
9,588	11,557,412
9,589	12,696,127
9,590	13,872,973
9,591	15,087,889
9,592	16,340,875
9,593	17,632,240
9,594	18,962,290
9,595	20,331,335
9,596	21,739,497
9,597	23,187,022

9,598	24,674,528
9,599	26,202,505
9,600	27,771,572
9,601	29,380,557
9,602	31,028,351
9,603	32,715,324
9,604	34,441,907
9,605	36,208,531
9,606	38,010,453
9,607	39,842,746
9,608	41,705,592
9,609	43,599,179
9,610	45,523,751
9,611	47,479,186
9,612	49,465,483
9,613	51,482,766
9,614	53,531,220
9,615	55,611,029
9,616	57,722,133
9,617	59,864,468
9,618	62,038,097
9,619	64,243,082
9,620	66,479,484
9,621	68,755,989
9,622	71,081,406
9,623	73,456,043
9,624	75,880,208

Table B.5 – Arequa Gulch PSSA 5 Filling Curve

Elevation	Storage Volume (gal)
9,720	0
9,721	17,451
9,722	70,125
9,723	155,181
9,724	279,015
9,725	449,643
9,726	678,374
9,727	974,969
9,728	1,336,842
9,729	1,779,375
9,730	2,364,873
9,731	3,193,581
9,732	4,271,185
9,733	5,454,092
9,734	6,714,263
9,735	8,015,363
9,736	9,368,945
9,737	10,774,426
9,738	12,232,323
9,739	13,743,282
9,740	15,307,886
9,741	16,927,944
9,742	18,603,133
9,743	20,334,099
9,744	22,121,359
9,745	23,965,559
9,746	25,868,381
9,747	27,829,436
9,748	29,849,240
9,749	31,928,377
9,750	34,067,363
9,751	36,264,065
9,752	38,513,958
9,753	40,817,303
9,754	43,174,420
9,755	45,585,570
9,756	48,051,010
9,757	50,568,802

9,758	53,139,075
9,759	55,762,088
9,760	58,437,969
9,761	61,167,882
9,762	63,951,181
9,763	66,787,931
9,764	69,678,324
9,765	72,622,427

SAFETY DATA SHEET

cyanco
Your Mining Solution

CYANCO® SODIUM CYANIDE, BRICKS 98% ± 1%

Doc. No.	COR-UNI-EHSS-SDS-002	Revision Date:	1/18/2013
Version	2.0 US	Print Date:	4/2/2013

This SDS adheres to the standards and regulatory requirements of the United States and may not meet the regulatory requirements of other countries.

SECTION 1. PRODUCT AND COMPANY IDENTIFICATION

Tradename/Synonym	:	Cyanco® Sodium Cyanide, Bricks 98% ± 1%
Product Use	:	For Industrial Use
Function	:	Electroplating Agent Gold Mining
Company	:	Cyanco 9450 Double R Blvd. Suite 2 Reno, NV 89521 USA
Medical Emergency		
US: Poison Control Center	:	800.222.1222
Transport Emergency		
US: CHEMTREC	:	800.424.9300
Canada: CANUTEC	:	613.996.6666
Product Information	:	832.590.3644
Telefax	:	713.436.5202
Contact Person	:	SDS Coordinator, 832.590.3644

SECTION 2. HAZARDS IDENTIFICATION

Emergency Overview



• Very toxic by inhalation, in contact with skin and if swallowed. • Contact with acids liberates very toxic gas. • Irritating to eyes and skin. • Very toxic to aquatic organisms. • May cause long-term adverse effects in the aquatic environment. • Causes severe eye burns. • Under the action of acids (as well as carbon dioxide) hydrocyanic acid is released which is combustible and may react with air to form explosive gas mixtures. • Hydrocyanic acid may cause all degrees of poisoning.

Precautions

Eye Contact	:	Corrosive. May cause burns resulting in permanent damage.
Skin Contact	:	Very toxic. May be fatal if absorbed through the skin.
Inhalation	:	Very toxic. May be fatal if inhaled.
Ingestion	:	Very toxic. May be fatal if swallowed.
Repeated Exposure	:	Adverse effects from long-term exposure may include: thyroid dysfunction, central nervous system effects.
Target Organs	:	Central Nervous System, Respiratory System, Thyroid
Carcinogenicity	:	None of the components in this material ≥ 0.1% are listed by OSHA, NTP or IARC as a carcinogen.
Potential Environmental Effect	:	Very toxic to aquatic organisms; may cause long-term adverse effects in the aquatic environment.

SECTION 3. COMPOSITION / INFORMATION ON INGREDIENTS

Information on Ingredients / Hazardous Components

Sodium Cyanide	CAS No.	143-33-9	Percent (Wt. / Wt.) 97 – 99%
	EC No.	205-599-4	

Other Information : This material is classified as hazardous under OSHA regulations.

SECTION 4. FIRST AID MEASURES

General Advice

WARNING!	If exposed to sodium cyanide, seek qualified medical attention immediately! Rescuers or medical responders should first of all protect themselves from exposure! Decontaminate the victim to prevent further absorption and exposure to rescuers and monitor vital signs.
Skin Contact	• No cases of cyanide intoxication have been observed to date following contact with dry sodium cyanide on dry skin free of injuries. However, if the dry sodium cyanide comes in contact with moisture or acids, then hydrogen cyanide may be released, causing cyanide intoxication. • May cause caustic burns to skin upon contact due to high pH. • Wash off immediately using large amounts of water (and soap if available) while removing all contaminated clothes and shoes. • Immediately contact or summon an emergency physician in case of intoxication symptoms.
Eye Contact	• In case of contact with the eyes, immediately flush eyes with copious amounts of water for a minimum of 15 minutes while removing clothes. • It is important to seek medical attention for all eye exposures due to potential caustic burns to the eyes. • Immediately contact or summon an emergency physician in case of intoxication symptoms. • An ophthalmologist should also be consulted for evaluation of caustic burns to the eyes. **Note:** Eye burns may not be apparent for up to 48 hours post exposure due to the caustic properties of sodium cyanide.
Inhalation	• Inhalation is possible if cyanide is in the form of aerosols, mists, dusts, or smoke. • Never perform direct mouth-to-mouth or mouth-to-nose artificial respiration. • Use artificial respiration bag or respirator due to the potential danger of poisoning the rescuers! • Maintain an open airway. • In case of breathing difficulties immediately apply oxygen. • Immediately contact an emergency physician and notify of cyanide / hydrocyanic acid poisoning.
Ingestion	• Thoroughly rinse mouth with water. • Seek professional medical care immediately. • Do not induce vomiting. • Call emergency physician immediately and notify of cyanide / hydro-cyanic acid poisoning. • Immediately transport to a medical facility.

Notes to Physician

IMPORTANT: Specific antidote and treatment may vary by region. If you are not familiar with current treatment recommendations, you should contact the Poison Control Center for your region or country for specific recommendations and guidelines.

Possible Signs of Poisoning Intoxication is classified by 2 categories:• Mild poisoning • Severe poisoning

The following symptoms are not sufficient to ensure a correct diagnosis:

Symptoms of the Central Nervous System	**Early Stage:** • headache • dizziness • drowsiness • nausea **Advanced Stage:** • seizures • coma
Pulmonary Symptoms	**Early Stage:** • dyspnea • tachypnea **Advanced Stage:** • hyperventilation • Cheyne-Stokes respiration • apnea

Cardiovascular Symptoms	**Early Stage:** • hypertension • sinus arrhythmia • atrioventricular arrhythmia • bradycardia **Advanced Stage:** • tachycardia • complex arrhythmia • cardiac arrest
Skin Symptoms	**Early Stage:** • rosy skin color **Advanced Stage:** • cyanosis
Effect on the Metabolism	Lactate acidosis: pH 7.1 and lactate level of 17 mmol/l are described.
Treatment	The treatment advice may vary by region. Contact a regional poison control center for appropriate antidote treatment used in your region.

CAUTION: This is an outline of antidotes available for informational purposes. It is important for the treating physician to be familiar with the administration of cyanide antidotes available in the country where the chemical is being used! Rapid treatment with appropriate antidote therapy is essential to saving lives during a high dose acute exposure to cyanide.

NOTE: Removal of toxic substance has equal importance to implementation of antidote therapy.

Mild Poisoning	• Treatment is dependent on clinical presentation with symptoms and history of exposure (related to dose). • 100% oxygen (medical grade) and artificial respiration if indicated. • Closely monitor patient and their vital signs (blood pressure, pulse and respirations). • Monitor the patient for onset of symptoms or deterioration of status. • Depending on the pathology and clinical findings, based on strictly monitored controls of the clinical findings, it may be necessary for the physician to implement symptom-oriented treatment for pulmonary edema prophylaxis. • X-rays of the lungs may be necessary for pulmonary edema diagnosis.
Severe Poisoning	• Specific antidote treatment can be indicated for moderate to severe cyanide intoxication. • It is important to know that there are several different types of antidotes available for treatment of cyanide intoxication in different countries.
For All Cyanide Exposure	• All cyanide exposed persons should undergo continued monitoring for several hours, even if patient feels well to ensure there are no residual or recurrent poisoning symptoms. • Artificial respiration with 100% oxygen (medical grade). • Immediate antidote administration with the legal antidote for the country of the exposure.

Commonly Used Antidotes

Met hemoglobin-Forming Agent

Nitrite Therapy: amyl nitrite, sodium nitrite, sodium thiosulfate.

For Moderate to Severe Exposures (patient still conscious)	Amyl Nitrite Aspirols: 1-3 aspirols administered as an inhalant, held 1-2 inches under the nose for 15 seconds, and then remove for 15 seconds. Read medication information insert prior to administering. Sodium nitrite 300-600 mg administered intravenously over a period of 5 to 15 minutes. Sodium thiosulfate (12.5 g - 100-500 mg/kg weight) intravenously over a period of 15-20 minutes. If patient is conscious, then Sodium thiosulfate may be administered as an antidote by itself: (See antidote package information insert). Sodium thiosulfate (12.5 g - 100-500 mg/kg weight) IV may be administered depending on the clinical presentation and symptoms.

Complexing Antidote Agent

Hydroxocobalamin - commonly known as the Cyanokit®.

Treatment as Follows:	Administer hydroxocobalamin (Cyanokit®) 5 g i.v. (70 mg/kg b.w. in adults) by infusion over a period of 20-30 minutes. Administration of this dose can be repeated as required depending on the severity of poisoning. Infusion time for repeated dose: 30 minutes to 2 hours. The only permissible route of administration for hydroxocobalamin is intravenously. The

physician should read the medication package information carefully to ensure proper reconstitution to liquid state and administration of antidote!

SECTION 5. FIRE-FIGHTING MEASURES

Flammable Properties

Flash Point	Not Combustible
Lower Explosion Limit	Not Applicable
Upper Explosion Limit	Not Applicable
Autoignition Temperature	Not Applicable
Suitable Extinguishing Media	Quenching Powder In case of fire in the surroundings: alkali powder quenching agent.
Unsuitable Extinguishing Media	Carbon dioxide (CO_2) must not be used for safety reasons.
Exposure Hazards During Fire Fighting	Hydrocyanic acid (hydrogen cyanide) may be released in case of fire.
Personal Protective Equipment for Fire Fighters	As in any fire, wear self-contained positive-pressure breathing apparatus, (MSHA/NIOSH approved or equivalent) and full protective gear.

Further Information

• Standard procedure for chemical fires. Ensure there are sufficient retaining facilities for water used to extinguish fire. • Water used to extinguish fire should not enter drainage systems, soil or stretches of water. • Contaminated fire-extinguishing water must be disposed of in accordance with the regulations issued by the appropriate local authorities. • Fire residues should be disposed of in accordance with local, state and federal regulations.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Personnel Precautions	• Wear personal protective equipment. • Keep out unprotected persons. • Keep unauthorized persons away. • Ensure sufficient ventilation. • Avoid skin contact because of the danger of skin absorption. • Make safe or remove all sources of ignition.
Environmental Precautions	• Do not allow entrance in soil, stretches of water, groundwater, drainage systems or surface water. • Cyanide-containing sewage water and solutions must be decontaminated before entering a public canal, network or stretch of water. • Do not use a neutralizing agent if runoff can enter nearby streams, rivers or other surface waterways. • On contact with acid, hydrogen cyanide in produced.
Methods for Cleanup in the Event of a Spill	• Pick up mechanically if in solid form. • Absorb with liquid-binding material e.g., inert absorbent if in solution. • Collect in suitable containers. • Dispose of material in accordance with local, state and federal regulations. • Waste to be packed like clean product and to be properly labeled. • Identification label on packages not to be removed until recycled.

SECTION 7. HANDLING & STORAGE

NOTE: Always have on hand a cyanide antidote kit and trained medical responders who can administer first aid before beginning work with this product.

Handling

Safe Handling Advice	• Container may be opened only under exhaust ventilation hood. • Seal container hermetically immediately after use. • Store under lock and key or in a way that qualified persons have access to it. • Use caution when opening the package, since toxic and caustic gases and vapors may escape.

Advice on Protection Against Fire and Explosion	• The product is not combustible. • See Section 5.

Storage

Requirements for Storage Areas and Containers	• Keep container tightly sealed and store in a dry, well-ventilated place. • Ensure there are sufficient retaining facilities for water used to extinguish fire.
Unsuitable Materials	• Aluminum • Brass • Copper
Advice on Common Storage	• Do not store together with acid and acidic salts. • Keep away from food, drink and animal feedstuffs.

SECTION 8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Product Occupational Exposure Guidelines

Sodium Cyanide	CAS-No. 143-33-9	EC No. 205-599-4
PEL (OSHA)	5mg/m^3 as CN 8-hr Time-Weighted Avg	Skin Designation
TLV (ACGIH)	5 mg/m^3 as CN Ceiling Limit	Skin Designation

Component Occupational Exposure Guidelines

Hydrogen Cyanide	CAS-No. 74-90-8	EC No. 200-821-6
PEL (OSHA)	10 ppm as CN 8-hr Time-Weighted Avg	Skin Designation
	11mg/m^3 as CN 8-hr Time-Weighted Avg	Skin Designation
TLV (ACGIH)	4.7 ppm as CN Ceiling Limit	Skin Designation
	5 mg/m^3 as CN Ceiling Limit	Skin Designation

Engineering controls • Engineer out the risk of exposure if feasible. • Ensure suitable ventilation at the work place and with operational machinery.

Personal Protective Equipment

Respiratory Protection • A respiratory protection program that meets OSHA 1910.134 and ANSI Z88.2 or applicable state/federal requirements must be followed whenever workplace conditions warrant respirator use. • NIOSH's "Respirator Decision Logic" may be useful in determining the suitability of various types of respirators.

Hand Protection • Natural Rubber • Nitrile • Polychrolorprene w/ natural latex rubber • PVC

Note: The above mentioned hand protection is based on knowledge of the chemistry and anticipated uses of this product but it may not be appropriate for all workplaces. A hazard assessment should be conducted prior to use to ensure suitability of gloves for specific work environments and processes prior to use.

Eye Protection • Impact resistant chemical protective goggles • Face-shield with brow guard

Skin and Body Protection	• Wear chemical protective suit. • During cleaning work wear rubber or plastic boots. • To identify additional Personal Protective Equipment (PPE) requirements, it is recommended that a hazard assessment in accordance with the OSHA PPE Standard (29CFR1910.132) be conducted before using this product. • A safety shower and eye wash fountain must be readily available. • Wash contaminated clothing before re-use.
Hygiene Measures	• Avoid contact with skin. • After contact with skin, wash immediately with plenty of water. • No eating, drinking, smoking, chewing gum or snuffing tobacco at work. • Wash face and/or hands before break and end of work.
Protective Measures	• All precautionary measures indicated have to be observed. • The work-place related airborne concentrations have to be kept below the indicated exposure limits. • If the limits at the workplace are exceeded and/or larger amounts are released (leakage, spilling, dust) the indicated respiratory protection should be used. (see above)

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Physical

Form	:	Solid
Color	:	White
Odor	:	Odorless **Note:** Can have bitter almond-like odor if hydrogen cyanide is present. Some people are unable to smell cyanide. Others can smell it at first, but then can be desensitized to the odor.

Chemical

pH	:	Approx 12.0 Aqueous Solution
Melting point/range	:	562 °C
Boiling point/range	:	1497 °C
Flash Point	:	Not Combustible
Flammability	:	Not Flammable
Autoignition Temperature	:	Not Applicable
Lower Explosion Limit	:	Not Applicable
Upper Explosion Limit	:	Not Applicable
Vapor Pressure	:	100 Pa at 800 °C
Density	:	Approx 1.6 g/cm^3 at 20 °C
Bulk Density	:	Aporox. 750 – 950 kg/m^3 Powder, Granulate, Pellets
Water Solubility	:	Approx. 379 g/l at 20 °C Approx. 450 g/l at > 35 °C
Partition Coefficient (N-octanol/water)	:	log Pow: -0.44 (calculated)

Further Information

Miscibility in Water	:	Completely Miscible

SECTION 10. STABILITY AND REACTIVITY

Materials to Avoid	• Under the action of acids (as well as carbon dioxide) hydrocyanic acid is released which is combustible and may react with air to form explosive gas mixtures. • Keep away from acidic salts.

Hazardous Decomposition Products	• HCN: Hydrogen cyanide (hydrocyanic acid) forms if heated above 300 °C.

SECTION 11. TOXICOLOGICAL INFORMATION

Sodium Cyanide

Acute Oral Toxicity	:	LD50 Rat: 5 mg/kg Method: Literature
Acute Dermal Toxicity	:	LD50 Rabbit(female): 11.8 mg/kg Method: Literature
Skin Irritation	:	Due to acute dermal toxicity, the irritative effect on the skin cannot be determined.
Eye Irritation	:	Rabbit Irritating
Repeated Dose Toxicity	:	Oral Rat Testing Period: 11½ months NOAEL: 75 mg/kg Target Organ/effect: thyroid, brain Feeding experiments Chronic Oral Rat Testing Period: 90 days NOAEL: approx. 0.3 mg/kg Target Organ/effect: reproductive system Drinking Water Analysis Subchronic toxicity Oral Mouse NOAEL: approx. 16.2 mg/kg Drinking Water Analysis Subchronic toxicity
Human Toxicity		• Inhalation is possible if cyanide is in the form of aerosols, mists, dusts, or smoke. • Very toxic by inhalation and if swallowed. • Inhaling of HCN (at already approx. 200 ppm HCN in the air breathed) or swallowing (approx. 200 - 300 mg NaCN) can result in immediate unconsciousness and death. • Can be absorbed through the skin. • Poisoning has an effect on the central nervous system. • Irritating to eyes, respiratory system and skin. • Following long-term exposure individual cases of thyroid dysfunction have been described with electroplaters and silver polishers.

SECTION 12. ECOLOGICAL INFORMATION

Elimination Information (Persistence and Degradability)

Biodegradability	:	Potentially biodegradable Abiotic degradation Hydrolysis
Bioaccumulation	:	Low
Mobility	:	In Air: High as HCN

Ecotoxicity Effects

Fish	:	LC50 Leuciscus idus melanotus: 0.07 mg/l
Daphnia	:	EC50 Daphnia magna: 0.3 mg/l
Bacteria	:	EC50 Escherichia coli: 0.004 mg/l

SECTION 13. DISPOSAL CONSIDERATIONS

Waste Disposal • Waste must be disposed of in accordance with local, state, provincial and federal laws and regulations. • Empty containers must be handled with care due to product residue.

SECTION 14. TRANSPORT INFORMATION

DOT / AAR / Sea Transport IMDG-Code

Class	:	6.1
UN Number	:	1689
Packing Group	:	1
Proper Shipping Name	:	SODIUM CYANIDE, SOLID
GHS Shipping Labels	:	
Marine Pollutant	:	Yes

Air Transport ICAO-TI/IATA-DGR

Class	:	6.1
UN Number	:	1689
Packing Group	:	1
Proper Shipping Name	:	SODIUM CYANIDE, SOLID
GHS Shipping Labels	:	

Loading Instructions/Remarks

IATA_C	:	ERG-Code 6L
IATA_P	:	ERG-Code 6L
IMDG	:	Do not stow in external container rows

Transport/Futher Information

Do not store together with acids (danger of toxic gases) or with foodstuffs, consumables and feedstuffs.

NOTE: Sodium cyanide is NOT a DOT TIH or PIH.

SECTION 15. REGULATORY INFORMATION

US Federal Regulations

OSHA — If listed below, chemical specific standards apply to the product or components:
- None Listed

CAA Section 112 — If listed below, components present at or above the de minimus level are hazardous air pollutants:
- Sodium Cyanide CAS No. 143-33-9

CERCLA Reportable Quantities — If listed below, a reportable quantity (RQ) applies to the product based on the percent of the named component:
- Sodium Cyanide CAS No. 143-33-9 Reportable Quantity: 10 lbs

SARA Title III Section 311/312 Hazard Categories — The product meets the criteria only for the listed hazard classes:
- Acute Health Hazard

SARA Title III Section 313 Reportable Substances	If listed below, components are subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 and 40 CFR Part 372: • Sodium Cyanide CAS No. 143-33-9 Reportable Quantity: 10 lbs
Toxic Substance Control Act (TSCA)	If listed below, non-proprietary substances are subject to export notification under Section 12 (b) of TSCA: • None Listed
State Regulations	
California Prop 65	A warning under the California Drinking Water Act is required only if listed below: • None Listed
Canadian Regulations	This SDS has been prepared in compliance with the Controlled Product Regulations except for use of the 16 headings.
WHMIS Classification	• D1 A • E
International Chemical Inventory Status	Unless otherwise noted, this product is in compliance with the inventory listing of the countries listed below.
Listed/registered:	• Europe (EINECS/ELINCS) • USA (TSCA) • Canada (DSL) • Australia (AICS) • Japan (MITI) • Korea (TCCL) • Philippines (PICCS) •China

European Union Risk and Safety Phrases

Risk Sodium cyanide is classified as toxic.

• R25 • R26 • R27 • R28 - Very toxic by inhalation, in contact with skin and if swallowed.
• R32 – Contact with acids liberates very toxic gas.
• R36 • R37 • R38 - Irritating to eyes, respiratory system and skin.
• R41 – Risk of serious damage to the eyes.
• R50 • R53 - Very toxic to aquatic organisms may cause long-term adverse effects in the aquatic environment.
• R55 • R56 • R57 - Toxic to fauna, soil organisms and bees.
• R67 - Vapors may cause drowsiness and dizziness.

Safety Sodium cyanide is a hazardous substance.

• S1 • S2 • S4 - Keep locked up, out of the reach of children and away from living quarters.
• S7 • S9 - Keep container tightly closed and in a well ventilated place.
• S13 • S14 - Keep away from food, drink and animal feeding stuffs, acids, acid salts and carbon dioxide fire extinguishers.
• S18 - Handle and open container with care.
• S20 • S21 - When using do not eat, drink or smoke.
• S22 - Do not breathe dust.
• S24 • S25 - Avoid contact with skin and eyes.
• S26 - In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.
• S27 - Take off immediately all contaminated clothing.
• S28 - After contact with skin, wash immediately with plenty of water.
• S29 - Do not empty into drains.
• S36 • S37 • S39 - Wear suitable protective clothing, gloves and eye/face protection.
• S38 - In case of insufficient ventilation, wear suitable respiratory equipment.
• S40 - To clean the floor and all objects contaminated by this material use sodium or calcium hypochlorite solution.
• S41 • S43 - In case of fire and/or explosion do not breathe fumes, use water, chemical powder or foam. Never use carbon dioxide.
• S45 - In case of accident or if you feel unwell seek medical attention immediately (show the label where possible).
• S46 • S64 - If swallowed, rinse mouth with water (only if the person is conscious), seek medical advice immediately and show this label.
• S50 - Do not mix with carbon dioxide, acids or acid salts

- S51 - Use only in well-ventilated areas.
- S53 - Avoid exposure – Obtain special instruction before use.
- S56 - Dispose of this material and its container to hazardous or special waste collection point
- S59 - Refer to manufacturer for information on recovery/recycling.
- S57 - Use appropriate containment to avoid environmental contamination.
- S61 - Avoid releases to the environment. Refer to special instructions/Safety data sheet.
- S63 - In case of accident by inhalation: remove casualty to fresh air and keep at rest.

SECTION 16. OTHER INFORMATION

HMIS Ratings Health: 3 Flammability: 0 Physical Hazard: 1

Further Information

This version replaces all previous versions.

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

Significant changes since the last version are highlighted in the margin with a double bar.

MATERIAL SAFETY DATA SHEET

Sodium Cyanide 30% Solution - UN3414

ABN: 81 008 668 371

Section 1 – Identification of the Material and Supplier

Product Name
Sodium Cyanide 30% Solution

Other names
Cyanide solutions NOS, Sodium cyanide solution, liquid cyanide. Company product 1360.

Recommended use
Extraction of gold and silver from ores.

Company name
CSBP Limited

Address	State	Postcode
Kwinana Beach Road, KWINANA	Western Australia	6167

Telephone number	Emergency telephone number
(08) 9411 8777 (Australia), +61 8 9411 8777 (Overseas)	1800 093 333 (Australia), +61 8 9411 8444

Section 2 – Hazard Identification

Hazard Classification, including a statement of overall hazardous nature

HAZARDOUS SUBSTANCE.

Sodium cyanide solution is classified as hazardous and specified in the NOHSC of Designated Hazardous Substances [NOHSC:10005(1999)].

DANGEROUS GOODS.

Sodium cyanide solution is classified for physicochemical hazards and specified as dangerous in the Australian Code for the Transport of Dangerous Goods by Road and Rail (ADG Code), 7th Edition, (FORS, 2007).

Risk Phrases

Sodium cyanide solution is classified as very toxic.

R25/26/27/28	Very toxic by inhalation, in contact with skin and if swallowed.
R32	Contact with acids liberates very toxic gas
R35	Causes severe burns
R36/37/38	Irritating to eyes/respiratory system and skin.
R41	Risk of serious damage to the eyes.
R50/53	Very toxic to aquatic organisms may cause long-term adverse effects in the aquatic environment.
R55/56/57	Toxic to fauna, soil organisms and bees.
R67	Vapours may cause drowsiness and dizziness.

Safety Phrases

Sodium cyanide is a hazardous substance.

S1/2/4	Keep locked up, out of the reach of children and away from living quarters.
S7/9	Keep container tightly closed and in a well ventilated place
S13/14	Keep away from food, drink and animal feeding stuffs, acids, acid salts and carbon dioxide fire extinguishers.
S18	Handle and open container with care.
S20/21	When using do not eat, drink or smoke.
S22	Do not breathe dust.
S24/25	Avoid contact with skin and eyes.
S26	In case of contact with eyes, rinse immediately with plenty of water and seek

	medical advice.
Safety Phrases (cont..)	
S27	Take off immediately all contaminated clothing.
S28	After contact with skin, wash immediately with plenty of water.
S29	Do not empty into drains.
S36/37/39	Wear suitable protective clothing, gloves and eye/face protection.
S38	In case of insufficient ventilation, wear suitable respiratory equipment.
S40	To clean the floor and all objects contaminated by this material use sodium or calcium hypochlorite solution.
S41/43	In case of fire and/or explosion do not breathe fumes, use water, chemical powder or foam. Never use carbon dioxide.
S45	In case of accident or if you feel unwell seek medical attention immediately (show the label where possible).
S46/64	If swallowed, rinse mouth with water (only if the person is conscious), seek medical advice immediately and show this label.
S50	Do not mix with carbon dioxide, acids or acid salts
S51	Use only in well-ventilated areas.
S53	Avoid exposure – Obtain special instruction before use.
S56	Dispose of this material and its container to hazardous or special waste collection point.
S59	Refer to manufacturer for information on recovery/recycling.
S 57	Use appropriate containment to avoid environmental contamination.
S61	Avoid releases to the environment. Refer to special instructions/Safety data sheet.
S63	In case of accident by inhalation: remove casualty to fresh air and keep at rest.

Poison Schedule

SUSDP Poison Schedule 7

Section 3 – Composition/Information on Ingredients

Chemical identity of ingredients	Proportion of ingredients	CAS Number for ingredients
Sodium cyanide	27 to 31·5 % ($^{wt}/_{wt}$)	143-33-9
Sodium carbonate	Less than 4 % ($^{wt}/_{wt}$)	497-19-8
Sodium formate	Less than 4 % ($^{wt}/_{wt}$)	141-53-7
Sodium hydroxide	Greater than 0·4 % ($^{wt}/_{wt}$)	1310-73-2
Ammonia	Less than 0·3 % ($^{wt}/_{wt}$)	7664-41-7
Water	Remainder	

MATERIAL SAFETY DATA SHEET

Sodium Cyanide 30% Solution - UN3414

ABN: 81 008 668 371

Section 4 – First Aid Measures

First Aid

TO BE EFFECTIVE, FIRST AID MUST BE PROMPT.

SODIUM CYANIDE SOLUTION IS POISONOUS BY INGESTION AND INHALATION OF ITS VAPOUR. CONTACT WITH SKIN AND EYES AND MAY CAUSE IRRITATION OF THE SKIN AND EYES AND POISONING SYMPTOMS SIMILAR TO THOSE FOR INGESTION.

OF PRIME IMPORTANCE IS THE PROTECTION OF THE RESCUER. NO ATTEMPT AT RESCUE SHOULD BE PERFORMED UNTIL AN APPROPRIATE HAZARD ASSESMENT OF THE EXPOSURE SITE IS MADE AND APPROPRIATE PERSONAL PROTECTION EQUIPMENT AND PERSONNEL ARE IN PLACE.

FIRST AID ATTENTION MUST BE GIVEN AS URGENTLY AS POSSIBLE AS OUTLINED BELOW. ALL SUSPECTED SODIUM CYANIDE INGESTION, INHALATION AND CONTACT SHOULD RECEIVE MEDICAL ATTENTION. TRAINING ON HANDLING SODIUM CYANIDE INCIDENTS USING THIS MSDS SHOULD BE PROVIDED BEFORE ANY SODIUM CYANIDE SOLUTION HANDLING OR USE COMMENCES.

First Aid Facilities

First aid procedures, equipment, medication and training for the treatment of exposure to sodium cyanide should be in place BEFORE the use commences. First aid personnel should be aware of the nearest hospitals which are familiar with the treatment of sodium cyanide exposure.

Equipment and medication in place should be:

Safety shower and eyewash stations immediately accessible in the workplace;

Eye-wash bottle;

Personal protective equipment for use by first aid personnel;

Fresh, clean, cool drinking water;

Resuscitation bag and mask (or Oxy-Viva);

Cyanide Emergency Kit: containing Amyl Nitrite Pearls; Hydroxycobalamine and Sodium Thiosulfate;

Oxygen;

"Space" or thermal blankets for treating patients for shock.

FIRST AID PROCEDURES FOR DEALING WITH THIS PRODUCT AND EXPOSURE TO IT

1. Personal Protection By First Aid Personnel

First aid personnel providing first aid treatment to a patient exposed to sodium cyanide solid should observe the following precautions for their own personal protection:

- Avoid contact with contaminated skin, clothing and equipment by wearing protective gloves;
- Wear chemical goggles as a minimum level of eye protection to prevent sodium cyanide solution entering eyes;
- Avoid inhalation of sodium cyanide vapour during rescue in contaminate areas by wearing suitable respiratory protection;
- Respiratory protection suggested is: an air supplied breathing apparatus, or positive pressure self-contained breathing apparatus.

2. Swallowed

Immediately:

- Remove the patient from the source of contamination – to fresh air, if hydrogen cyanide gas (HCN) is present;
- If the patient is not breathing, do not use mouth to mouth, or mouth to nose ventilation, because of the danger to the rescuer, instead use a resuscitation bag and mask – (Oxy-Viva);
- If pulse is absent, start external cardiac massage and follow standard Advanced Cardiovascular Life Support (ACLS) guidelines;
- Give 100% oxygen by mask (Oxy-Viva) if available;
- Remove all contaminated clothing and footwear into a sealable collection bag – launder contaminated clothing thoroughly and wash the affected areas with soap and copious amounts of

water;

2. Swallowed (cont..)

- Arrange for the urgent transfer of the patient, accompanied by an attendant with the Cyanide Emergency Kit, to medical professionals;
- Those persons designated as competent may open the Cyanide Emergency Kit and commence use of any amyl nitrite pearls to treat the effects of cyanide exposure.

  Amyl Nitrite should not be used unless the patient is clearly deteriorating, despite oxygen administration, and there is a reasonable confidence that cyanide intoxication is the cause.

3. Eyes

Persons with potential eye exposure should not wear contact lenses.

Immediately irrigate eye with copious amounts of water, while holding eyelids open, for at least 15 minutes.

Seek medical assistance immediately.

4. Skin

Wash affected area with copious amounts of water for at least 15 minutes.

Remove contaminated clothing and launder before re-use.

Seek medical assistance following skin contact.

5. Inhalation

Proceed as for **2. Swallowed** above.

ADVICE TO DOCTOR.

Treatment should include the following measures:

- Immediate attention should be directed towards assisted ventilation, administration of 100 % oxygen, insertion of intravenous lines and institution of cardiac monitoring, if available;
- Attention should be given to monitoring the level of consciousness;
- Administer antidote if signs of serious cyanide poisoning are present:
  - Insert indwelling cannula into vein:
  - Take 5 mL of blood in a plain clotted tube (red top in Western Australia) for later confirmation of diagnosis by measurement of the cyanide level. (Take blood in a heparinised tube and place on ice for immediate transfer to laboratory if direct testing for cyanide levels is available). At the same time take blood for lactic acid level (urgent). An elevated lactic acid level is a useful test to assist in confirmation of the diagnosis.

    Note: Cyanide poisoning is a clinical diagnosis and treatment is instigated on clinical grounds.
- Treatment path
  - Administer intravenously 5 to 15 grams of hydroxycobalamine over 30 minutes, or faster if necessary. In the Cyanide Emergency Kit these are made up of two 2·5 gram doses that are set to be re-constituted with the saline in the plastic transfer device. An IV giving set is to be inserted into the re-constituted IV hydroxycobalamine bottle. If this has been left in the cardboard packet, it can be hung like an IV bottle through the hole in the top of the box;
  - Also administer sodium thiosulfate 12·5 grams over 10 to 20 minutes with the hydroxycobalamine;

    Note: Hydroxycobalamine is the recommended treatment in patients in whom the diagnosis is not clear and where there is a clinical suspicion of cyanide poisoning.
  - If cyanide has been swallowed, whilst gastric lavage, charcoal and cathartics may be used after an antidote therapy, if less than two hours have passed since ingestion, there is little evidence to support a benefit and one should take the advice of an emergency care physicians prior to commencing;
  - Obtain an arterial blood gas measurement immediately, and correct any severe metabolic acidosis (pH below 7·20) with bicarbonate;

    Note: The best way to treat metabolic and cardiorespiratory complications of cyanide poisoning is the use of an appropriate antidote.

Supportive care should include the following measures:

- All patients with suspected, or proven, cyanide poisoning should be taken to hospital for evaluation and observation:
- Follow the patient's progress for at least 24 hours;
- Watch for the development for pulmonary oedema and aspiration pneumonia in comatose patients;
- Consider more antidote if there is a persistent metabolic acidosis. Bicarbonate can be used cautiously. Correct metabolic acidosis with bicarbonate when blood pH falls below 7·20, and be sure to correct electrolyte imbalance (for example, hyperkalemia, hypercalcemia);
- Oxygen requirement would be expected to decrease after successful administration of the antidote.

Long Term Complications

No data available.

Further information about the treatment for exposure to this product can be obtained from the Poisons Information Centre on (08) 13 1126 (Australia only)

Section 5 – Fire Fighting Measures

Product flammability

Sodium cyanide solution is not combustible and is not considered a fire risk, but may generate toxic, flammable, corrosive and explosive hydrogen cyanide gas if in contact with water, CO_2 fire extinguishers, and some foam fire extinguishers if these contain acidic agents.

Suitable extinguishing media

DO NOT USE CARBON DIOXIDE. Extinguish fires with water spray or fog. Do not use straight stream of water. Most foams will react with sodium cyanide solution and release toxic and corrosive fumes. For small fires use dry chemical extinguishers or dry sand.

Hazard from combustion products

Although sodium cyanide itself is not combustible, intense heat may cause sodium cyanide to decompose, giving off toxic, flammable, corrosive and explosive hydrogen cyanide gas.

Special protective precautions and equipment for fire fighters

Wear full body protective clothing (PVC jackets and pants, PVC gloves and chemical resistant boots) with self-contained breathing apparatus with a full-face piece operated in pressure-demand or positive pressure mode. Prevent spillage from entering drains or waterways. Consider evacuation. Use water to control fire. Spilled sodium cyanide solution will cause surfaces to be slippery and slimy. If required, use soda ash, or other suitable alkaline material, to control the pH of the water/cyanide mixture created. If safe and practicable to do so remove sodium cyanide containers from path of fire.

Equipment should be thoroughly decontaminated after use.

After intervention, take shower, remove clothing carefully, clean and check equipment.

Hazchem Code

2X

Section 6 – Accidental Release Measures

Emergency procedures

The hazardous nature of sodium cyanide solution requires emergency and spill procedures to be effective to avoid both human and environmental exposure. Hazardous conditions may result if material is managed improperly. Make plans in advance to handle possible emergencies, including obtaining stocks of absorbent materials.

Always wear recommended personal protective equipment and respiratory protection. Good ventilation is necessary.

Methods and Materials for containment and clean up

For **ALL** spills, evacuate unprotected personnel upwind and out of danger. Wear appropriate personal protective equipment and breathing apparatus. If safe to do so, prevent further release of sodium cyanide solution. Shut off all possible sources of ignition. Stay upwind of any dust or mist released. Increase ventilation and allow any dust or mist released to vent to a safe area. Restrict access to spill site. If possible contain the surface area of a sodium cyanide solution spill by bunding with sand, earth or vermiculite. Avoid, or minimise, the use of water on spillage. Recover as much material as possible into dedicated drums and return to manufacturer. Using a shovel/front end loader as required, recover as much neutralised material as possible into dedicated drums for proper disposal accordance with the requirements of the Department of Environment Protection. For a large spill notify Fire and Rescue Services then CSBP Emergency Response.

Initial Clean Up With Ferrous Sulfate

Generously cover any remaining residue with lime or soda ash (to maintain pH at 9 or higher), add ferrous sulfate then add water and mix well. Allow about 30 minutes for complete penetration and neutralisation to take effect. Collect residue and store in dedicated container for disposal. Prevent run-off into drains and waterways. After clean up, test area for free cyanide level present; if free cyanide is more than 10 parts per million (ppm), repeat clean up using ferrous sulfate; if free cyanide is less than 10 ppm proceed with final clean up using hypochlorite solution.

Final Clean Up With Calcium/Sodium Hypochlorite

Make up a dilute aqueous chlorine solution using either calcium hypochlorite or sodium hypochlorite. Spray this chlorine solution evenly to the area to be decontaminated. After thorough contact of the chlorine solution with the contaminated area is made, test area for free cyanide present. If free cyanide is more than 1 ppm, repeat clean up using chlorine solution. Prevent run-off into drains and waterways.

For the management of cyanide emergencies during transport by road or rail, SAA/SNZ HB76: Dangerous Goods-Initial Response Guide, Guide 40 should be consulted. This Guide should be carried at all times when sodium cyanide is being transported.

Clean up personnel will need personal full protection equipment and respiratory protection. Portable safety shower and eyewash facilities may also be needed for clean up personnel. Bags of ferrous sulfate neutralising agent, calcium/sodium hypochlorite drums, bags of soda ash, or other suitable alkaline material, chemical absorbent and substantial amounts of water will be required for large spill. A front-end loader may be required to scoop up neutralised cyanide/lime/soda ash residue, as are dedicated empty drums to store the neutralised residue.

Section 7 – Handling and Storage

Precautions for safe handling

Regulated dangerous goods as Class 6.1 Toxic. Proper protective clothing must be worn that covers the body including the face. A safety shower and eyewash should be available. Do not breathe vapour or mist. Avoid contact with skin, eyes and clothing.

Do not smoke anywhere near the storage and handling of sodium cyanide solution or associated handling equipment.

Do not touch damaged containers or spilled material unless wearing appropriate personal protective equipment.

Change and wash clothing, and personal protective equipment if contaminated, or before storing and/or re-using. Wash hands and face thoroughly after handling and before work breaks, eating, drinking, smoking and using toilet facilities.

Conditions for safe storage, including any incompatibilities

Ensure sodium cyanide solution in bulk is stored and handled in accordance with Australian Standard AS 4452 *The storage and handling of toxic substances* and Dangerous Goods Safety Act 2004 (*Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007*). Ensure adequate ventilation to keep airborne concentration below exposure standard. Where necessary, use local exhaust ventilation in conjunction with P2 canister respirator, or as appropriate, self contained breathing apparatus.

Keep workplaces and stores well ventilated. Above a correctly stored quantity of sodium cyanide solution there is a presence of hydrogen cyanide (HCN) gas. HCN is very slightly denser than air and disperses rapidly in air. Toxic concentrations of HCN can be reached when sodium cyanide solution is in prolonged contact with air in a closed area. HCN is flammable and, when its concentration in air is in the range of 5·4 to 46·6 % ($^{vol}/_{vol}$), it forms explosive mixtures. The concentration of HCN above sodium cyanide solution increases with decreasing pH of the sodium cyanide solution and with increasing ambient temperature of the solution. Sodium cyanide 30% solution manufactured by CSBP is stabilised against the effects of acidification by the presence of 0·4 % ($^{wt}/_{wt}$) free sodium hydroxide in the solution. Measurements indicate that in an unventilated space above sodium cyanide 30 % solution at 30 °C, the approximate HCN concentration is between 100 to 150 parts per million (ppm). At 40 °C, the HCN concentration is approximately between 150 to 200 ppm.

Store away from acids –sodium cyanide will release toxic and flammable hydrogen cyanide gas in contact with acids. Store away from chlorinating agents. Contact with these may form toxic cyanogen chloride gas. Incompatible with oxidizing agents, copper, zinc, magnesium, tin, or their alloys (i.e., bronze, brass, galvanised metals, etc.) and aluminium.

Section 8 – Exposure Controls/Personal Protection

National exposure standards

ES-TWA	ES-STEL	ES-Peak
5 mg/m^3 as Cyanide (CN^-) dust	No data assigned by NOHSC	No data assigned by NOHSC
10 ppm as Hydrogen Cyanide (HCN)	Peak Limitation	Peak Limitation

Biological limit values

No data available.

Engineering controls

Handle sodium cyanide solution within closed systems whenever possible. Provide adequate ventilation at all times.

Personal protective equipment

Whenever the risk of exposure exists, such as opening sodium cyanide solution storage tank valves, non-routine operations and emergency circumstances, the following personal protection measure are recommended:

Respiratory protection

Canister respirator P2 type if air sampling indicates hydrogen cyanide level is between 11 and 50 mg/m^3 (Australian Standard *AS 1716 Respiratory protective devices*). Air supplied, or positive pressure, self contained breathing apparatus recommended where air sampling indicates hydrogen cyanide gas concentration exceeds 50 mg/m^3.

Hand protection

PVC or butyl rubber gauntlet-type gloves.

Eye protection

Chemical splash goggles (gas tight type preferred) and full face shield.

Skin protection

PVC overalls or jacket and pants and butyl rubber Wellington boots.

MATERIAL SAFETY DATA SHEET

Sodium Cyanide 30% Solution - UN3414

ABN: 81 008 668 371

Section 9 – Physical and Chemical Properties

Appearance (colour, physical form, shape)
Clear, colourless to red-brown liquid.

Odour
Appreciable ammonia odour

pH
Neat solution pH 13.

Vapour pressure
2·3 kPa at 20 °C

Vapour density
0·93 (Air =1)

Boiling point/range
109 °C at 101·3 kPa.

Freezing/melting point
Crystallises between 2 and 5 °C at 101·3 kPa.

Solubility
Solubility in all proportions in water; sparingly soluble in ethanol.

Specific gravity or density
Specific Gravity: 1·16 to 1·19 at 25 °C.

Flash point and method of detecting flash point
Not applicable

Upper and lower flammable (explosive) limits in air
Not applicable

Ignition temperature
Not applicable

Viscosity

Temperature (°C)	Viscosity (mPa.s)
21·5	10·3
30	7·6

Temperature (°C)	Viscosity (mPa.s)
50	2·0
80	0·9

Section 10 – Stability and Reactivity

Chemical stability
Stable at ambient conditions of use and storage.

Conditions to avoid
Contact with water, acids, acid salts and carbon dioxide lead to the liberation of hydrogen cyanide gas.

Incompatible materials
Incompatible with oxidizing agents, copper, zinc, magnesium, tin, or their alloys (i.e., bronze, brass, galvanised metals, etc.) and aluminium.

Hazardous decomposition products
Toxic and flammable hydrogen cyanide gas (HCN). Hydrogen gas forms explosive mixtures in air when air contains HCN in the range of 5·4 to 46·6 % ($^{vol}/_{vol}$).

Hazardous reactions
Store away from acids, acid salts, water & carbon dioxide fire extinguishers – sodium cyanide will release toxic and flammable hydrogen cyanide gas in contact with these substances. Store away from chlorinating

agents – contact may form toxic cyanogen chloride gas. Exothermic reactions with oxidizing agents.

Section 11 – Toxicological Information

HEALTH EFFECTS

When handled in accordance with the guidelines in this material safety data sheet, sodium cyanide 30 % solution should not present any health effects. If this product is mishandled, the following symptoms may develop:

Acute:

Sodium cyanide 30 % solution is a very toxic chemical asphyxiant – may cause death soon after exposure by all means of entry into the human body. It may cause caustic burns in contact with human flesh. Cyanide inhibits cytochrome oxidase preventing oxygen utilization leading to cytotoxic anoxia. Acute effects depend on the degree of histotoxic hypoxia. Death results from central nervous system failure. Venous blood remains oxygenated and victim may appear pink,

Inhalation:

Inhalation of sodium cyanide 30 % solution vapour – ammonia (NH_3) gas or hydrogen cyanide (HCN) gas above the solution - may result in burns and irritation to the nose and upper respiratory tract, leading to coughing and sore throat. Lesions of the nasal septum and delayed pulmonary oedema may result. Toxic amounts of HCN may be inhaled leading to poisoning symptoms which include weakness, headache, dizziness, shortness of breath, chest pain, confusion, cyanosis (bluish skin due to deficient oxygenation of the blood), weak and irregular heartbeat, collapse, unconsciousness, coma and death. Death can be very rapid. The lethal oral dose of HCN is estimated to be approximately 50 mg in an adult (Sullivan, J.B. Jr., G.R. Krieger (eds.), *Hazardous Materials Toxicology-Clinical Principles of Environmental Health,* Baltimore, Williams and Wilkins, 1992).

Human physiological response to various concentrations of hydrogen cyanide in air are summarised below:

HCN Level in		Duration in minutes	Resulting Conditions on Humans
mg/m^3	ppm		
2·2 - 5·5	2 - 5	-	"Bitter almonds" smell detectable by some people.
11	10	-	NOHSC peak limitation exposure standard.
19·8 - 39·6	18 -36	Several hours	Slight symptoms of cyanide poisoning.
48·5 -59·4	45 - 54	30 - 60 minutes	Tolerated without immediate or delayed effects.
121 - 148·5	110 - 135	30 - 60 minutes	Fatal, or dangerous to life.
148·5	135	30 minutes	Fatal.
199·1	181	10 minutes	Fatal.
297	270	Immediately	Immediately fatal.

(Simenova, F., Fishbein, L., Concise International Chemical Assessment Document 61, *Hydrogen Cyanide and Cyanides: Human Health Aspects*, International Program in Chemical Safety, Geneva, World Heath Organisation, 2004).

Skin:

Contact with sodium cyanide 30 % solution will cause severe irritation and chemical burns. Sweat increases rate of absorption into skin. Toxic amounts of sodium cyanide may be absorbed through the skin, leading to poisoning symptoms similar to those for inhalation. Toxicity tests: for sodium cyanide 30 % solution LD_{50} (Dermal, human/30 minutes) = 10 mg/kg (DSM Acrylonitrile B.V *Safety Data Sheet*, Ver. 5, 20/12/04); for sodium cyanide LD_{50} (Dermal, rat) = 33 mg/kg.

Eye:

Contact with sodium cyanide 30 % solution will cause severe irritation to the eye, leading to redness, pain and possible eye burns. May cause chemical conjunctivitis and corneal damage leading to loss of sight. Toxic amounts of sodium cyanide may be absorbed through the eye, leading to poisoning symptoms similar to those for inhalation.

Swallowed:

Sodium cyanide 30% solution is very toxic and may be fatal if swallowed. It will cause caustic burns, resulting in severe gastrointestinal tract irritation with nausea and vomiting, accompanied by severe burning sensation. Toxic amounts of sodium cyanide ingested may lead to poisoning symptoms similar for those for inhalation. The mean lethal dose by mouth of cyanide (CN^-) in an 80 kg male human adult is thought to be in the range of 50 to 200 mg and death is rarely delayed more than one hour (Gosselin *et al*, *Clinical Toxicology of Commercial Products*. 5th Ed., Baltimore: Williams and Wilkins, 1984). Toxicity tests: for sodium cyanide 30 % solution LD_{50} (Oral, rat) = 25 mg/kg (DSM Acrylonitrile B.V *Safety Data Sheet*, Ver. 5, 20/12/04); for sodium cyanide LD_{50} (Oral, rat) = 6·44 mg/kg.

Chronic:

Cyanide (CN^-) may be highly acutely toxic, but it has lower toxicity on a chronic basis. Prolonged or repeated exposure may cause drying of the skin, dermatitis, ulceration, skin necrosis, loss of appetite, weight loss, dizziness, shortness of breath, muscle cramps and irritation to upper respiratory tract. Chronic cyanide intoxication has been associated with such human diseases as retro tubular neuritis in pernicious anaemia, Leber's optic atrophy and Nigerian nutritional Neuropathy. Following long-term exposure at 15 ppm levels, individual cases of thyroid dysfunction have been reported (Barnerjee *et al*, Evaluation of cyanide exposure and its effect on thyroid function on workers in a cable industry, *J Occup Environ Med.*, 39(3):258-260, 1997). As acutely toxic as cyanide is, repeated low-level doses of cyanide do not necessarily result in cumulative adverse effects.

Section 12 – Ecological Information

Ecotoxicity

Fish and aquatic invertebrates are very sensitive to cyanide (CN^-) exposure. Small concentrations, in the range of 5 to 20 mg CN^- per litre, causes a reduction in swimming performance, inhibiting reproduction and altering growth patterns. Increased cyanide concentrations in the range of 30 to 200 mg/L causes the deaths of many species of fish and invertebrates. Algae and macrophytes can tolerate much higher environmental concentrations of free cyanide than fish and invertebrates, but cyanide exposures may leave an aquatic plant community dominated by less sensitive species. Birds and higher mammals are susceptible to cyanide poisoning and display many symptoms associated with humans exposed to cyanide. The rapid recovery of some birds to sub-lethal doses of cyanide may be due to the rapid metabolism of cyanide to thiocyanate and its subsequent excretion. Cyanide has low persistence and is not accumulated or stored in any mammal studied.

Persistence and degradability

Potentially biodegradable by abiotic degradation. In aerobic conditions, microbial activity degrades cyanide ion (CN^-), in concentration up to 200 parts per million, to ammonia which then oxidises to nitrate (NO_3). Biological degradation may also occur under anaerobic conditions, but CN^- concentrations of more than 2 ppm are toxic to anaerobic micro organisms. Hydrogen cyanide may be hydrolysed to formic acid or ammonium formate- this reaction is not fast but may be appreciable faster in anaerobic conditions such as ground water.

- Water/Soil – in soils cyanide ion (CN^-) migrates easily to ground water and at high concentrations is toxic to soil micro organisms;
- Groundwater – persists in groundwater due to lack of sunlight/oxygen needed to degrade it to benign forms.

Mobility

- Air – HCN present as gas – duration 1-3 years before settling out;

In alkaline conditions, due to the presence of 0·4 % ($^{wt}/_{wt}$) free sodium hydroxide in sodium cyanide 30 % solution:

- Water – considerable solubility and mobility – at surface water interface cyanide ion (CN^-) oxidises in the presence of sunlight and oxygen to yield cyanate ion (CNO^-), thiocyanate ion (SCN^-), ammonia, nitrate (NO_3) and various other compounds;
- Soil/Sediments – adsorption on minerals soil constituents possible - most persistent in groundwater

and at higher pH.

Environmental fate (exposure)

Acute ecotoxicity:

Fish: 96 hr LC_{50} (Oncorhyncus mykiss): 0·1 mg/L, (as sodium cyanide 30% solution); in fresh water conditions*;

Crustaceans: 48 hr EC_{50} (Daphnia magna): 0·1 mg/L, (as sodium cyanide 30% solution), in fresh water conditions*;

Fish: 96 hr LD_{50} (Oncorhyncus mykiss): 0·028 mg/L, (as cyanide); in fresh water conditions at 6 °C;

Fish: 96 hr LD_{50} (Perca flavescens): 0·076 - 0·108 mg/L, (as cyanide); in fresh water conditions;

Fish: 96 hr LD_{50} (Pimephales promolas): 0·082 - 0·113 mg/L, (as cyanide); in fresh water conditions;

Crustaceans: 96 hr LD_{50} (Daphnia magna): 0·16 mg/L, (as cyanide), in fresh water conditions;

Soil organisms: 96 hr EC_{50} (Lumbriculus variegatus): 11 mg/L, (as cyanide);

Terrestrial plants: 32 days EC_{50} (Pimephales promolas): 22·4 mg/L, (as cyanide);

Birds: 96 days EC_{50} (Lymnaea luteola): 2·5 mg/L, (as cyanide).

* DSM Acrylonitrile B.V *Safety Data Sheet*, Ver. 5, 20/12/04

Bioaccumulative potential

Low potential for human bioaccumulation. Does not bioaccumulate in fish.

Section 13 – Disposal Considerations

Disposal methods and containers

Due to its inherent properties, hazardous conditions may result if material is managed improperly. Dispose of all contained and contaminated spill residue in accordance with the requirements of the Department of the Environment. Contact CSBP Limited for technical advice on disposal method.

As required under the ADG Code treat empty containers as filled containers.

Special precautions for landfill or incineration

No data available

Section 14 – Transport Information

UN Number

3414

UN Proper shipping name

Sodium Cyanide solutions

Class and subsidiary risk

Class 6.1 Toxic. No subsidiary risk.

Packing group

I

Special precautions for user

Transport in accordance with Australian Code for Transport of Dangerous Goods by Road and Rail (ADG Code).

Hazchem code

2X

Section 15 – Regulatory Information

Australian regulatory information

SUSDP Poison Schedule 7. Licensing is required for this chemical in all States and Territories.

Listed on the Australian Inventory of Chemical Substances (AICS).

Additional national and/or international regulatory information

MATERIAL SAFETY DATA SHEET

Sodium Cyanide 30% Solution - UN3414

CSBP

SAFE PERSON • PROCESS • PLACE

ABN: 81 008 668 371

OSHA: Hazardous by definition of Hazard Communication Standard (29CFR 1910.1200).
This product is subject to the EC directive 82/501/EEC and amendments.

Section 16 – Other Information

Key / legend to abbreviations and acronyms used in the MSDS

NOEC	No Observable Effect Concentration - concentration where no effect can be seen
NOHSC	National Occupational Health and Safety Commission
SUSDP	Standard for the Uniform Scheduling of Drugs and Poisons
EC_{50}:	Environmental concentration 50. The concentration of a material, in ppm or ppb, in the environment (usually water) a single dose of which is expected to cause a biological effect on 50% of a group of test animals.
ES-TWA	Exposure Standard – Time weighted average
ES-STEL	Exposure Standard – Short term exposure level
ES-Peak	Exposure Standard – Peak level
FORS	Federal Office of Road and Safety
LC_{50}:	Lethal concentration 50, median lethal concentration
LD_{50}	Lethal dose 50. The single dose of a substance that causes the death of 50% of an animal population from exposure to the substance by any route other than inhalation
$\%(^{wt}/_{wt})$	Percent amount on a weight per weight basis
$\%(^{wt}/_{vol})$	Percent amount on a weight per volume basis
PPM	Parts per million
Zone 1 Class 1	An area where an explosive gas atmosphere can be expected to occur periodically or occasionally during normal operation. (More than 10 hours per year but less than 1000 hours per year)

Literature references

Occupational Safety and Health Regulations 1996, State Law Publisher, Western Australia.

National Code of Practice for the Preparation of Material Safety Data Sheets, [NOHSC:2011(2003)], Australian Government Publishing Service, Canberra, April 2003.

Australian Code for the Transport of Dangerous Goods by Road and Rail, 7th Edition, Australian Government Publishing Service, Canberra, October 2007.

Chemical Rubber Handbook, D.R. Lide, CRC Press, 65th Edition, Boca Ratón, 1987.

Perry's Chemical Engineers' Handbook, R.H. Perry & D. Green, 6th Edition, McGraw-Hill, New York, 1984.

International Critical Tables of Numerical Data, Physics, Chemistry and Technology, National Research Council, 1st Edition, McGraw-Hill, New York, 1928.

Condensed Chemical Dictionary, G.G Hawley, 8th Edition, Van Nostrand Reinhold, New York, 1950.

Dangerous Properties of Industrial Chemicals, N.I.Sax & R.J. Lewis (Sr), 7th Edition, Van Nostrand Reinhold, New York, 1984.

Patty's Industrial Hygiene and Toxicology, F.A. Patty, 3rd Revised Edition, G.D. & F.E. Clayton (Editors), John Wiley & Sons, New York, 1981.

Matheson Gas Data Book, W.Braker & A.L. Mossman, 6th Edition, Matheson Gas Products, Secaucus, 1980.

Encyclopaedia of Occupational Health and Safety, International Labour Office, 4th Edition, J.M. Stellman (Editor), Geneva, 1998

Kirk-Othmer Encyclopaedia of Chemical Technology, 4th Edition, Wiley InterScience, New York, 1997.

Ullmann's Encyclopaedia of Industrial Chemistry, F. Ulmann, 6th Edition, Wiley Interscience, New York, 2001.

MATERIAL SAFETY DATA SHEET

Sodium Cyanide 30% Solution - UN3414

ABN: 81 008 668 371

Standard for the Uniform Scheduling of Drugs and Poisons, National Health and Medical Research Council, Australian Government Publishing Service, Canberra, 1992.

Poisons Act 1964, State Law Publisher, Western Australia, Reprinted 22 January 1999.

Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environmant, [NHSC:1003(1991)].

Hazardous Materials Handbook for Emergency Responders, Onguard Training for Life, J. Varela (Editor), Van Nostrand Reinhold, New York, 1996.

Chemalert www.chemalert.net

Guidance for the Compilation of Safety Data Sheets for Fertilizer Materials, European Fertilizer Manufacturers Association, online at www.efma.org/Publications/Guidance/Index.asp

Sources for data

Important Notes

1. To the best of our knowledge this document complies with the National Code of Practice for the Preparation of Material Safety Data Sheets 2nd Edition [NOHSC:2011 (2003)].
2. This material safety data sheet summarises our best knowledge of the health and safety hazard information of the product and how to safely handle and use the product in the workplace. Each user should read this material safety data sheet and consider the information in the context of how the product will be handled and used in the workplace, including in conjunction with other products.
3. If clarification or further information is needed to ensure that an appropriate risk assessment can be made, the user should contact the Safety and Emergency Services Department, CSBP Limited on (08) 9411 8777 (Australia), +61 8 9411 8777 (Overseas).
4. Our responsibility for products sold, is subject to our terms and conditions, a copy of which is sent to our customers, and is also available on request.
5. CSBP reserves the right to make change to material safety data sheets without notice.

World Headquarters
Hach Company
P.O.Box 389
Loveland, CO USA 80539
(970) 669-3050

MSDS No: M00438

MATERIAL SAFETY DATA SHEET

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product Name: Sodium Hydroxide Solution 5.0 N
Catalog Number: 245053

Hach Company
P.O.Box 389
Loveland, CO USA 80539
(970) 669-3050

Emergency Telephone Numbers:
(Medical and Transportation)
(303) 623-5716 24 Hour Service
(515)232-2533 8am - 4pm CST

MSDS Number: M00438
Chemical Name: Not applicable
CAS No.: Not applicable
Chemical Formula: Not applicable
Chemical Family: Not applicable
UN Number/PIN: 1824
Intended Use: Laboratory Use Standard solution
Date of MSDS Preparation:
Day: 18
Month: February
Year: 2014
MSDS Prepared: MSDS prepared by Product Compliance Department extension 3350

2. HAZARDS IDENTIFICATION

Emergency Overview:
Appearance: Clear, colorless
Physical State: Liquid
Odor: Odorless
CAUSES SEVERE BURNS
HMIS:
Health: 3
Flammability: 0
Reactivity: 1
Protective Equipment: X - See protective equipment, Section 8.
Potential Health Effects:
Eye Contact: Causes severe burns
Skin Contact: Causes severe burns May cause: scarring
Skin Absorption: None Reported
Target Organs: None Reported
Ingestion: Causes: severe burns
Target Organs: None reported
Inhalation: Causes: severe burns May cause: pneumonitis
Target Organs: None reported
Medical Conditions Aggravated: Pre-existing: Eye conditions Respiratory conditions Skin conditions
Chronic Effects: Chronic overexposure may cause destruction of any tissue contacted
Cancer / Reproductive Toxicity Information:
This product does NOT contain any IARC listed chemicals.
This product does NOT contain any NTP listed chemicals.
Additional Cancer / Reproductive Toxicity Information: None reported
Toxicologically Synergistic Products: None reported
WHMIS Hazard Classification: Class E - Corrosive material
WHMIS Symbols: Corrosive

3. COMPOSITION / INFORMATION ON INGREDIENTS

Sodium Hydroxide
Percent Range: 15.0 - 25.0
Percent Range Units: weight / weight
CAS No.: 1310-73-2
LD50: Oral rat LDLo = 500 mg/kg
LC50: None reported
TLV: Not established
PEL: 2 mg/m³
Ingredient WHMIS Symbol: Corrosive

Demineralized Water
Percent Range: 75.0 - 85.0
Percent Range Units: weight / weight
CAS No.: 7732-18-5
LD50: LD50 oral rat = >89,800 mg/kg
LC50: None reported
TLV: Not established
PEL: Not established
Ingredient WHMIS Symbol: Not applicable

4. FIRST AID MEASURES

Eye Contact: Immediately flush eyes with water for 15 minutes. Check for and remove any contact lenses. Call physician.
Skin Contact (First Aid): Wash skin with plenty of water for 15 minutes. Remove contaminated clothing. Call physician immediately.
Ingestion (First Aid): Do not induce vomiting. Rinse mouth with plenty of water. Give 1-2 glasses of water. If vomiting occurs, avoid aspiration by keeping head below hips. Never give anything by mouth to an unconscious person. Call physician immediately.
Inhalation: Remove to fresh air. Call physician.

5. FIRE FIGHTING MEASURES

Flammable Properties: Material is not classified as flammable according to GHS criteria. Material will not burn.
Flash Point: Not applicable
Method: Not applicable
Flammability Limits:
Lower Explosion Limits: Not applicable
Upper Explosion Limits: Not applicable
Autoignition Temperature: Not applicable
Hazardous Combustion Products: This material will not burn.
Fire / Explosion Hazards: This product will not burn or explode. May react violently with: strong acids
Static Discharge: None reported.
Mechanical Impact: None reported
Extinguishing Media: Use media appropriate to surrounding fire conditions
Fire Fighting Instruction: As in any fire, wear self-contained breathing apparatus pressure-demand and full protective gear. Evacuate area and fight fire from a safe distance.

6. ACCIDENTAL RELEASE MEASURES

Spill Response Notice:
Only persons properly qualified to respond to an emergency involving hazardous substances should respond to a spill involving chemicals. See Section 13, Special Instructions for disposal assistance.

Containment Technique: Releases of this material may contaminate the environment. Stop spilled material from being released to the environment. Absorb spilled liquid with non-reactive sorbent material. Dike the spill to contain material for later disposal.
Clean-up Technique: Cover spilled material with a dry acid, such as citric or boric. Scoop up slurry into a large beaker. Dilute with a large excess of water. Adjust to a pH between 6 and 9 with an acid, such as sulfuric or citric. Decontaminate the area of the spill with a weak acid solution. If permitted by regulation, Flush reacted material to the drain with a large excess of water. Otherwise, Pick up spill for disposal and place in a closed container Dispose of in accordance with local, state and federal regulations or laws.
Evacuation Procedure: Evacuate local area (15 foot radius or as directed by your facility's emergency response plan) when: any quantity is spilled. If conditions warrant, increase the size of the evacuation.
D.O.T. Emergency Response Guide Number: 154

7. HANDLING AND STORAGE

Handling: Avoid contact with eyes skin clothing Wash thoroughly after handling. Use with adequate ventilation. Do not breathe mist or vapors. Maintain general industrial hygiene practices when using this product.
Storage: Keep container tightly closed when not in use. Keep this product in its original container when not in use. Store in a cool, dry place. Store locked up. Keep away from: acids / acid fumes. Protect from: heat freezing

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Engineering Controls: Have an eyewash station nearby. Have a safety shower nearby. Use general ventilation to minimize exposure to mist, vapor or dust.
Personal Protective Equipment:
Eye Protection: chemical splash goggles Suitable facilities (eyewash station or bottle) for flushing of the eyes
Skin Protection: lab coat neoprene latex gloves Suitable facilities for quickly drenching or flushing skin after chemical exposure should be available.
Inhalation Protection: adequate ventilation and / or laboratory fume hood
Precautionary Measures: Avoid contact with: eyes skin clothing Wash thoroughly after handling. Use with adequate ventilation. Do not breathe: mist/vapor Keep away from: acids/acid fumes Protect from: heat freezing
TLV: 2 mg/m^3
PEL: 2 mg/m^3

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance: Clear, colorless
Physical State: Liquid
Molecular Weight: Not applicable
Odor: Odorless
pH: 14
Vapor Pressure: Estimation: 15.73 mm Hg (2.04 kPa) at 20 °C (68 °F)
Vapor Density (air = 1): 0.62
Boiling Point: 107 °C (224 °F)
Melting Point: -24 °C (-12 °F)
Specific Gravity/ Relative Density (water = 1; air =1): 1.181
Evaporation Rate (water = 1): 0.59
Volatile Organic Compounds Content: None.
Coefficient of Water / Oil: Not applicable
Solubility:
Water: Miscible.
Acid: Miscible.
Other: Soluble in methanol, ethanol, and glycerol.
Metal Corrosivity:
Steel: 0.00 in/yr (0.00 mm/yr)
Aluminum: > 20 in/yr (> 508 mm/yr)

10. STABILITY AND REACTIVITY

Chemical Stability: Stable when stored under proper conditions.
Conditions to Avoid: Extreme temperatures Excessive heat Freezing conditions Contact with acid or acid fumes

Reactivity / Incompatibility: Incompatible with: acids
Hazardous Decomposition: No hazardous decomposition products known.
Hazardous Polymerization: Will not occur.

11. TOXICOLOGICAL INFORMATION

Product Toxicological Data:
LD50: None reported.
LC50: None reported.
Dermal Toxicity Data: None reported.
Skin and Eye Irritation Data: None reported.
Mutation Data: None reported.
Reproductive Effects Data: None reported.
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Ingredient Toxicological Data: Sodium Hydroxide: Oral rat LDLo = 500 mg/kg; Several skin and eye irritation test results reported in RTECS.

12. ECOLOGICAL INFORMATION

Product Ecological Information: Aquatic Toxicity Estimation: 96 hr Oncorhynchus mykiss LC50 = 227 mg/L; 48 hr Crustaceans EC50 = 202 mg/L
No ecological data available for this product. Based on classification principles, not classified as hazardous to the environment. No bioaccumulation potential Mobility in soil: Highly mobile
Ingredient Ecological Information: 96 hr Oncorhynchus mykiss LC50 = 45.4 mg/L; 48 hr Daphnia sp. EC50 = 100 mg/L; 48 hr Crustaceans EC50 = 40.4 mg/L
CEPA categorization for ingredients are as follows:

13. DISPOSAL CONSIDERATIONS

Special Instructions (Disposal): Work in an approved fume hood. Dilute to 3 to 5 times the volume with cold water. Adjust to a pH between 6 and 9 with an acid, such as sulfuric or citric. If permitted by regulation, Open cold water tap completely, slowly pour the reacted material to the drain. Allow cold water to run for 5 minutes to completely flush the system. Otherwise, Check with local municipal and state authorities and waste contractors for pertinent local information regarding the proper disposal of chemicals.
Empty Containers: Working in a well-ventilated area, Rinse three times with an appropriate solvent. Collect rinsate and dispose of according to local, state or federal regulations. In the US, rinsate from empty containers is classified as hazardous waste and should be disposed of at an E.P. A. approved facility. Rinsate from empty containers may contain sufficient product to require disposal as hazardous waste. Dispose of empty container as normal trash.
NOTICE (Disposal): These disposal guidelines are based on federal regulations and may be superseded by more stringent state or local requirements. Please consult your local environmental regulators for more information.

14. TRANSPORT INFORMATION

T.D.G.:
Proper Shipping Name: Sodium Hydroxide Solution
--
Hazard Class: 8
UN Number/PIN: 1824
Packing Group: II
Subsidiary Risk: NA
Additional Information: There is a possibility that this product could be contained in a reagent set or kit composed of various compatible dangerous goods. If the item is NOT in a set or kit, the classification given above applies. If the item IS part of a set or kit, the classification would change to the following: UN3316 Chemical Kit, Class 9, PG II or III. If the item is not regulated, the Chemical Kit classification does not apply.

15. REGULATORY INFORMATION

National Inventories:
Canadian Inventory Status: All ingredients of this product are DSL Listed.

This product has been classified in accordance with the hazard criteria of the CPR and the MSDS contains all of the information required by the CPR.

16. OTHER INFORMATION

References: 29 CFR 1900 - 1910 (Code of Federal Regulations - Labor). Air Contaminants, Federal Register, Vol. 54, No. 12. Thursday, January 19, 1989. pp. 2332-2983. CCINFO RTECS. Canadian Centre for Occupational Health and Safety. Hamilton, Ontario Canada: 30 June 1993. IARC Monographs on the Evaluation of the Carcinogenic Risks to Humans. World Health Organization (Volumes 1-42) Supplement 7. France: 1987. List of Dangerous Substances Classified in Annex I of the EEC Directive (67/548) - Classification, Packaging and Labeling of Dangerous Substances, Amended July 1992. Sixth Annual Report on Carcinogens, 1991. U.S. Department of Health and Human Services. Rockville, MD: Technical Resources, Inc. 1991. Technical Judgment. TLV's Threshold Limit Values and Biological Exposure Indices for 1992-1993. American Conference of Governmental Industrial Hygienists, 1992.

Legend:

NA - Not Applicable	w/w - weight/weight
ND - Not Determined	w/v - weight/volume
NV - Not Available	v/v - volume/volume

USER RESPONSIBILITY: Each user should read and understand this information and incorporate it in individual site safety programs in accordance with applicable hazard communication standards and regulations.

THE INFORMATION CONTAINED HEREIN IS BASED ON DATA CONSIDERED TO BE ACCURATE. HOWEVER, NO WARRANTY IS EXPRESSED OR IMPLIED REGARDING THE ACCURACY OF THESE DATA OR THE RESULTS TO BE OBTAINED FROM THE USE THEREOF.

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Anachemia

Material Safety Data Sheet

EMERGENCY NUMBERS:

(USA) CHEMTREC : 1(800) 424-9300 (24hrs)
(CAN) CANUTEC : 1(613) 996-6666 (24hrs)
(USA) Anachemia : 1(518) 297-4444
(CAN) Anachemia : 1(514) 489-5711

WHMIS	Protective Clothing	TDG Road/Rail
WHMIS CLASS: E D-1A		TDG CLASS: 8 PIN: UN1789 PG: II
		

Section I. Product Identification and Uses

Product name	HYDROCHLORIC ACID
Chemical formula	HCl
Synonyms	Muriatic acid, Chlorohydric acid, Hydrogen chloride, AC-4955, AC-4955PG, AC-4955SP, AC-4955T, AC-4955GC, CD-4955, EP-4955, EG-4955, R-2830S, 46475, 46414, 46416, 46549, 46390, 46396, 46399, 46405
Supplier	Anachemia Canada. 255 Norman. Lachine (Montreal), Que H8R 1A3
Material uses	For laboratory use only.

CI#	Not available.
CAS#	7647-01-0
Code	AC-4955
Formula weight	36.46
Supersedes	

Section II. Ingredients

Name	CAS #	%	TLV
1) HYDROCHLORIC ACID (expressed as HCl)	7647-01-0	30-38	Exposure limits: ACGIH Ceiling limit 2 ppm (3 mg/m3)
2) WATER	7732-18-5	Balance	Not established by ACGIH

Toxicity values of the hazardous ingredients

HYDROCHLORIC ACID:
ORAL (LD50): Acute: 900 mg/kg (Rabbit).
VAPOR (LC50): Acute: 3124 ppm (Rat) (1 hour(s)). 1108 ppm (Mouse) (1 hour(s)).
VAPOR (LCLo): Acute: 1300 ppm (Human) (30M).

Section III. Physical Data

Physical state and appearance / Odor	Colorless fuming liquid with a pungent odor.
pH (1% soln/water)	0.1 (1M solution)
Odor threshold	5-10 ppm
Percent volatile	100% (V/V)
Freezing point	-46.2 to -25.4°C
Boiling point	108 to 110°C
Specific gravity	1.16 to 1.19 (Water = 1)
Vapor density	1.3 (Air = 1)
Vapor pressure	150 to 160 mm of Hg (@ 20°C)
Water/oil dist. coeff.	Not available.
Evaporation rate	>1
Solubility	Miscible in water.

Section IV. Fire and Explosion Data

Flash point	Not applicable.
Flammable limits	Not applicable.
Auto-ignition temperature	Not available.
Fire degradation products	Hydrogen chloride gas.
Fire extinguishing procedures	Use extinguishing media suitable for surrounding materials. Wear adequate personal protection to prevent contact with material or its combustion products. Self contained breathing apparatus with a full facepiece operated in a pressure demand or other positive pressure mode. Cool containing vessels with flooding quantities of water until well after fire is out. DO NOT get water inside container.
Fire and Explosion Hazards	Flammable/explosive hydrogen gas may be formed upon contact of this product with metals. The sensitivity to impact is not applicable. The sensitivity to static discharge is not applicable. Emits toxic and corrosive fumes under fire conditions.

Section V. Toxicological Properties

Routes of entry	Inhalation and ingestion. Eye contact. Skin contact.
Effects of Acute Exposure	Harmful by ingestion, inhalation or skin absorption. Corrosive. Target organs: skin, eyes, lungs, respiratory system. 50 ppm (HYDROCHLORIC ACID) is immediately dangerous to life or health.
Eye	Vapors, liquids and mists are extremely corrosive to the eyes. Brief contact of the vapors will be severely irritating. Brief contact of the liquid or mist will severely damage the eyes and prolonged contact may cause permanent eye injury which may be followed by blindness.
Skin	Causes severe burns. Severe pain and brownish or yellow stains: usually penetrates the full thickness of the skin. Lesser exposures may cause dermatitis and photosensitization.
Inhalation	Material is extremely destructive to tissue of the mucous membranes and upper respiratory tract. Inhalation may be fatal as a result of spasm, inflammation and edema of the larynx and bronchi, chemical pneumonitis and pulmonary edema. Symptoms of exposure may include burning sensation, coughing, laryngitis, dyspnea, headache, nausea, and vomiting. Can cause lung damage.
Ingestion	Burns in mouth, pharynx and gastrointestinal tract. Weakness from falling blood pressure, nausea, vomiting, dysphagia, abdominal pain, cardiovascular collapse, convulsions, coma and death possible. Asphyxia may occur from edema of the glottis.

Section V. Toxicological Properties

Effects of Chronic Overexposure	Erosion of the teeth, ulceration of the nose, mouth and gums, bronchitis. Repeated or prolonged skin contact can cause severe dermatitis or burns. Carcinogenic effects: Not available. Mutagenic effects: Not available. Teratogenic effects: Not available. Toxicity of the product to the reproductive system: Not available. To the best of our knowledge, the chemical, physical, and toxicity of this substance has not been fully investigated.

Section VI. First Aid Measures

Eye contact	Immediate first aid is needed to prevent eye damage. Immediately flush eyes with copious quantities of water for at least 30 minutes holding lids apart to ensure flushing of the entire surface. Speed is essential. Seek immediate medical attention. Do not use chemical antidotes.
Skin contact	Immediately flush skin with plenty of water for at least 30 minutes while removing contaminated clothing and shoes. Do not use chemical antidotes. Speed is essential. Seek immediate medical attention. Wash contaminated clothing before reusing. Discard contaminated leather articles such as shoes and belt.
Inhalation	Remove patient to fresh air. Administer approved oxygen supply if breathing is difficult. Administer artificial respiration or CPR if breathing has ceased. Call a physician.
Ingestion	If conscious, wash out mouth with water. Have conscious person drink several glasses of water or milk, repeating if vomiting. DO NOT induce vomiting. Aim to dilute acid 100 times approximately. Seek immediate medical attention. Never give anything by mouth to an unconscious or convulsing person.

Section VII. Reactivity Data

Stability	Stable. Conditions to avoid: High temperatures, sparks, open flames and all other sources of ignition, contamination.
Hazardous decomp. products	Not available.
Incompatibility	Reacts with most common metals to produce hydrogen. Amines, metal oxides, acetic anhydride, beta-propiolacetone, vinyl acetate, mercuric sulfate, calcium phosphide, formaldehyde, alkalies, carbonates, bases, sulfuric acid, chlorosulfonic acid, nitric acid, oxidizing agents, cyanides, sulfides, fluorides, phosphides, acetylides, bromides, carbides, silicides, hydroxides, propylene oxide, fluorine, water reactive materials, silver perchlorate, carbon tetrachloride, perchloric acid, 2-aminoethanol, ammonium hydroxide, ethylenediamine, ethyleneimine, oleum, copper and aluminum and their alloys, alkali metals, sulfites.
Reaction Products	Will corrode a wide variety of metals. Hazardous polymerization will not occur.

Section VIII. Preventive Measures

Protective Clothing in case of spill and leak	Wear self-contained breathing apparatus, rubber boots and heavy rubber gloves. Full suit.
Spill and leak	Evacuate and ventilate the area. Cover with soda ash or lime. This will release carbon dioxide, so use caution. Place in a suitable container and mark for disposal. Wash spill site after material pick up is complete. DO NOT empty into drains. DO NOT touch damaged container or spilled material. Stay upwind: Keep out of low areas.
Waste disposal	According to all applicable regulations. Harmful to aquatic life at high concentrations. Can be dangerous if allowed to enter drinking water intakes. Do not contaminate domestic or irrigation water supplies, lakes, streams, ponds, or rivers.
Storage and Handling	Store in a cool place away from heated areas, sparks, and flame. Store in a well ventilated area. Store away from incompatible materials. Do not add any other material to the container. Do not wash down the drain. Do not breathe gas/fumes/vapor/spray. In case of insufficient ventilation, wear suitable respiratory equipment. Keep away from direct sunlight or strong incandescent light. Keep container tightly closed and dry. Manipulate under an adequate fume hood. Protect from moisture. Do not use pressure to dispense. May corrode metallic surfaces. Empty containers may contain a hazardous residue. Handle and open container with care. Take off immediately all contaminated clothing. This product must be manipulated by qualified personnel. Do not get in eyes, on skin, or on clothing. Wash well after use. In accordance with good storage and handling practices. Do not allow smoking and food consumption while handling. Wear suitable protective clothing. In case of accident or if you feel unwell, seek medical advice immediately (show the label when possible.).

Section IX. Protective Measures

Protective clothing	Face shield and splash goggles. Impervious gloves (neoprene), apron, coveralls, and/or other resistant protective clothing as required for workplace conditions to prevent contact with hydrochloric acid solutions. Sufficient to protect skin. None required if handled in closed ventilation system. Where required (leak, spill, open handling of liquid) use a NIOSH-approved chemical cartridge respirator for gas below 50 ppm. For gas above 50 ppm or mist, use NIOSH approved self-contained breathing apparatus or air-supplied respirator, both with full facepieces. Have available and use as appropriate: suits, aprons, and boots. Do not wear contact lenses. Make eye bath and emergency shower available. Ensure that eyewash station and safety shower is proximal to the work-station location.
Engineering controls	Use in a chemical fume hood to keep airborne levels below recommended exposure limits. Ventilation should be corrosion proof. Do not use in unventilated spaces.

Section X. Other Information

Special Precautions or comments	Corrosive! Toxic! Causes severe burns! Risk of serious damage to eyes. Do not breathe vapor. Avoid all contact with the product. Avoid prolonged or repeated exposure. Use in a chemical fume hood. Handle and open container with care. Container should be opened only by a technically qualified person. Solutions are highly corrosive. Synergistic materials: Not available. RTECS NO: MW4025000 (Hydrochloric acid).



NFPA

Prepared by MSDS Department/Département de F.S..

Validated 30-Oct-2014

While the company believes the data set forth herein are accurate as of the date hereof, the company makes no warranty with respect thereto and expressly disclaims all liability for reliance thereon. Such data are offered solely for your consideration, investigation and verification.

FloMin Inc.

MATERIAL SAFETY DATA

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product name: **Flomin C 3505 Collector**
Chemical Name: Potassium amyl xanthate (PAX)
Synonyms: Dithio-O-amyl ester
Molecular Formula: $C_5H_{11}OCS_2K$
Molecular Weight: 202.4
Manufacturer: Flomin Inc. **www.flomin.com**
7500 FM 1405
Baytown, TX 77523
Tel: 281-573-3912; Fax: 281-573-4921
Emergency Phones: 800-424-9300 CHEMTREC (North America)
+1-703-527-3887 CHEMTREC (Worldwide)
912-884-3366 (Flomin Inc., 24-Hour)

2. HAZARDS IDENTIFICATION

WARNING! Product is spontaneously combustible. Avoid contact with heat, moist air, and water. Product dust or mist may be irritating to nose, throat, and respiratory system. Product dust and liquid solutions may cause eye and skin burns. Harmful if swallowed. Excessive heating or contact with moisture may liberate toxic and flammable carbon disulfide (CS_2).

POTENTIAL HEALTH EFFECTS: *(See Section 11 for toxicological data.)*

Eye: Mild to severe irritant. May cause tearing, blurring of vision and corneal damage.

Skin: Mild to severe skin irritant. Effects of prolonged skin contact may include rash and burns.

Ingestion: Ingestion can cause irritation or burns of the mouth, throat, esophagus, and stomach with nausea and vomiting. Central nervous system effects may include headaches, weakness, and nausea.

Inhalation: Prolonged inhalation of mist or dust may cause irritation to the nose, throat and respiratory system. Central nervous system effects may include headaches, weakness, dizziness and nausea. Excessive heating or contact with moisture can release poisonous, flammable carbon disulfide gas. Carbon disulfide has a characteristic "garlic like" odor. The TWA (8-hour) exposure level for carbon disulfide is 20 ppm. The IDLH exposure level for carbon disulfide sulfide is 500 ppm.

3. COMPOSITION / INFORMATION ON INGREDIENTS

Component	***CAS #***	***Weight, %***	***Exposure Limit***
Potassium amyl xanthate	2720-73-2	90 ± 3	Not established

4. FIRST AID MEASURES

Inhalation: Move to fresh air immediately. Administer oxygen if necessary. Seek medical attention if symptoms persist.

Skin contact: Remove contaminated clothing immediately and wash affected skin with soap and water. Get medical treatment for burns and persistent irritation. Launder contaminated clothing before reuse.

Eye contact: Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician. Keep eye wide open while rinsing and lift upper and lower lids to ensure complete removal of chemical.

Ingestion: Do not induce vomiting. Drink large quantities of water. Call a physician immediately.

5. FIRE FIGHTING MEASURES

Flammable properties:

	PAX	***CS_2***
- ***Flash point***	Not applicable	-22°F (-30°C) TAG CC
- ***Flammable limits***	Not applicable	LEL = 0.6%, UEL = 60%
- ***Autoignition temp.***	Not determined	194-203°F (90-95°C)
- ***Decomposition temp.***	Not determined	Not determined

Extinguishing media: Use carbon dioxide, dry chemical, or dry sand.

Fire fighting precautions: Avoid contact with dusts, mists and liquids. Keep personnel removed and upwind of fire.

Protective equipment: Wear NIOSH approved, positive pressure, self-contained respirator. Wear full protective equipment for body and eyes.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions: Wear full protective equipment for eyes, body and respiratory system. Ventilate spill area. Remove all sources of ignition.

Clean up methods: Sweep up solid spills and place in closed containers for reuse or disposal. Do not place solids for disposal in trash receptacles or open containers; keep separate from all other waste materials and discard as soon as practical. Flush cleaned up spill area with water.

Contain liquid xanthate spills with absorbent materials and collect for reuse or disposal. Place spill material at pH >12 in lined or plastic containers and reuse or discard within 30 days

Environmental: Keep flush material out of waterways. Dispose of all cleanup materials in an approved manner.

7. HANDLING AND STORAGE

Handling: Avoid static electricity discharge when opening and transferring material from containers. Wear protective equipment for eyes, body and respiratory system. Provide adequate ventilation in work area.

Storage: Solid xanthates are relatively stable and may be stored up to one (1) year if kept dry and cool. Keep solids in tightly sealed containers in a cool area away from sources of heat or ignition.

Liquid xanthates have a limited shelf life of thirty (30) days and must be stored at temperatures < 86°F (<30°C) and at a high pH >12. Liquid xanthates will lose at least 1-2% activity per week at higher temperatures, and will totally decompose at a pH <9.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Personal protection equipment:

- ***Respiratory:*** Wear a properly fitted NIOSH/MSA approved respirator whenever significant exposure to vapor or dust is likely.
- ***Hand:*** Neoprene, polyvinyl, butyl rubber or nitrile rubber gloves are suitable.
- ***Eye:*** Wear chemical splash proof goggles or face shield.
- ***Skin:*** Wear coveralls and/or chemical apron and rubber footwear where physical contact can occur.

Hygiene: Wash hands before breaks and immediately after handling the product. Do not eat or store food and drinks where this product is used.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Light yellow to green pellets
Odor:	Disagreeable
Boiling point:	Not applicable
Melting point:	522°F (272°C)
Vapor pressure:	Not applicable
Bulk density:	~40 lbs/cu. ft. (~0.64 g/cc)
Vapor density:	Not applicable (Air =1)
Flash Point:	Not applicable (-22°F (-30°C) TAG CC for Carbon Disulfide)
pH:	Not applicable (>12 for aqueous solutions)
Water solubility:	Soluble
Viscosity:	Not applicable

10. STABILITY AND REACTIVITY

Stability: Stable at normal conditions. No hazardous polymerization will occur.

Conditions to avoid: High temperatures and ignition sources. Avoid moisture, strong acids & oxidizing agents. Not compatible with copper or its alloys.

Hazardous decomposition Products: Carbon disulfide, amyl alcohol, carbon monoxide and carbon dioxide may form under fire conditions.

11. TOXICOLOGICAL INFORMATION

Acute toxicity:

- ***Oral:*** Acute oral LD_{50} (rat) = 1000 - 2000 mg/kg for 10% solution
- ***Dermal:*** Not determined
- ***Inhalation:*** Not determined

Irritation:

- ***Skin:*** Mild to severe skin irritant.
- ***Eyes:*** Mild to severe eye irritant.

Sensitization: May sensitize some individuals toward asthmatic conditions and allergic skin reactions.

12. ECOLOGICAL INFORMATION

Aquatic toxicity: Not determined

Biodegradation: Not determined

13. DISPOSAL CONSIDERATIONS

Disposal: Dispose of only in accordance with regulations. Do not contaminate any lakes, streams, ponds, groundwater or soil.

Containers: Empty containers retain product residues (solid and vapor) and can be dangerous. Do not cut or burn or expose empty containers to heat, flame or sources of ignition. Empty containers should be completely emptied and disposed in accordance with regulations.

14. TRANSPORT INFORMATION

Agency	***UN#, Proper shipping name, Hazard class, Packing group, Advisory placard***
DOT:	UN 3342, Xanthates, 4.2, III, SPONTANEOUSLY COMBUSTIBLE This product is regulated as a hazardous material as defined by the DOT.
IMO:	UN 3342, Xanthates, 4.2, III, SPONTANEOUSLY COMBUSTIBLE This product is regulated as a dangerous good as defined by the IMDG code for marine transport.
ICAO/IATA:	UN 3342, Xanthates, 4.2, III, SPONTANEOUSLY COMBUSTIBLE This product is regulated as a dangerous good as defined by the ICAO/IATA for air transport.
Canada:	UN 3342, Xanthates, 4.2, III, SPONTANEOUSLY COMBUSTIBLE This product is regulated as a dangerous good as defined by the WHIMS classification.

15. REGULATORY INFORMATION

Components of this product are listed on the TSCA (US), DSL (Canada), EINECS (Europe), and AICS (Australia) inventories.

SARA 302: Contains no chemicals subject to 40 CFR 302 reporting.

SARA 311/312: Immediate (acute) health hazard, fire hazard, reactive.

SARA 313: Contains no chemicals subject to 40 CFR 313 reporting.

16. OTHER INFORMATION

Hazard Ratings:

	Health	***Flammability***	***Instability***	***Physical Hazard***
- NFPA	2	2	1	---
-HMIS	2	2	---	1

THE ABOVE INFORMATION IS BELIEVED TO BE ACCURATE AND REPRESENTS THE BEST INFORMATION CURRENTLY AVAILABLE TO US. HOWEVER, WE MAKE NO WARRANTY OF MERCHANTABILITY OR ANY OTHER WARRANT, EXPRESSED OR IMPLIED, WITH RESPECT TO SUCH INFORMATION, AND WE ASSUME NO LIABILITY FOR ITS USE. USERS SHOULD MAKE THEIR OWN INVESTIGATIONS TO DETERMINE THE SUITABILITY OF THE INFORMATION FOR THEIR PARTICULAR NEEDS.

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Material Safety Data Sheet

SECTION 1 PRODUCT AND COMPANY IDENTIFICATION

Chevron Drive Train Fluid HD

Product Use: Transmission Fluid

Product Number(s): CPS226601, CPS226607, CPS226608, CPS226610

Synonyms: Chevron Drive Train Fluid HD SAE 10W, Chevron Drive Train Fluid HD SAE 30, Chevron Drive Train Fluid HD SAE 50, Chevron Drive Train Fluid HD SAE 60

Company Identification

Chevron Products Company

a division of Chevron U.S.A. Inc.

6001 Bollinger Canyon Rd.

San Ramon, CA 94583

United States of America

www.chevronlubricants.com

Transportation Emergency Response

CHEMTREC: (800) 424-9300 or (703) 527-3887

Health Emergency

Chevron Emergency Information Center: Located in the USA. International collect calls accepted. (800) 231-0623 or (510) 231-0623

Product Information

email : lubemsds@chevron.com

Product Information: (800) LUBE TEK

MSDS Requests: (800) 414-6737

SECTION 2 COMPOSITION/ INFORMATION ON INGREDIENTS

COMPONENTS	CAS NUMBER	AMOUNT
Highly refined mineral oil (C15 - C50)	Mixture	80 - 100 %weight
Zinc alkyl dithiophosphate	68649-42-3	1 - 5 %weight

SECTION 3 HAZARDS IDENTIFICATION

IMMEDIATE HEALTH EFFECTS

Eye: Not expected to cause prolonged or significant eye irritation.

Skin: Contact with the skin is not expected to cause prolonged or significant irritation. Contact with the skin is not expected to cause an allergic skin response. Not expected to be harmful to internal organs if absorbed through the skin. High-Pressure Equipment Information: Accidental high-velocity injection under the skin of materials of this type may result in serious injury. Seek medical attention at once should an accident like this occur. The initial wound at the injection site may not appear to be serious at first; but, if left untreated, could result in disfigurement or amputation of the affected part.

Ingestion: Not expected to be harmful if swallowed.

Inhalation: Not expected to be harmful if inhaled. Contains a petroleum-based mineral oil. May cause respiratory irritation or other pulmonary effects following prolonged or repeated inhalation of oil mist at airborne levels above the recommended mineral oil mist exposure limit. Symptoms of respiratory irritation may include coughing and difficulty breathing.

SECTION 4 FIRST AID MEASURES

Eye: No specific first aid measures are required. As a precaution, remove contact lenses, if worn, and flush eyes with water.

Skin: No specific first aid measures are required. As a precaution, remove clothing and shoes if contaminated. To remove the material from skin, use soap and water. Discard contaminated clothing and shoes or thoroughly clean before reuse.

Ingestion: No specific first aid measures are required. Do not induce vomiting. As a precaution, get medical advice.

Inhalation: No specific first aid measures are required. If exposed to excessive levels of material in the air, move the exposed person to fresh air. Get medical attention if coughing or respiratory discomfort occurs.

Note to Physicians: In an accident involving high-pressure equipment, this product may be injected under the skin. Such an accident may result in a small, sometimes bloodless, puncture wound. However, because of its driving force, material injected into a fingertip can be deposited into the palm of the hand. Within 24 hours, there is usually a great deal of swelling, discoloration, and intense throbbing pain. Immediate treatment at a surgical emergency center is recommended.

SECTION 5 FIRE FIGHTING MEASURES

Leaks/ruptures in high pressure system using materials of this type can create a fire hazard when in the vicinity of ignition sources (eg. open flame, pilot lights, sparks, or electric arcs).

FIRE CLASSIFICATION:

OSHA Classification (29 CFR 1910.1200): Not classified by OSHA as flammable or combustible.

NFPA RATINGS: Health: 0 Flammability: 1 Reactivity: 0

FLAMMABLE PROPERTIES:

Flashpoint: (Cleveland Open Cup) 190 °C (374 °F) Minimum

Autoignition: No Data Available

Flammability (Explosive) Limits (% by volume in air): Lower: Not Applicable Upper: Not Applicable

EXTINGUISHING MEDIA: Use water fog, foam, dry chemical or carbon dioxide (CO2) to extinguish flames.

PROTECTION OF FIRE FIGHTERS:

Fire Fighting Instructions: This material will burn although it is not easily ignited. For fires involving this material, do not enter any enclosed or confined fire space without proper protective equipment, including self-contained breathing apparatus.

Combustion Products: Highly dependent on combustion conditions. A complex mixture of airborne solids, liquids, and gases including carbon monoxide, carbon dioxide, and unidentified organic compounds will be evolved when this material undergoes combustion.

SECTION 6 ACCIDENTAL RELEASE MEASURES

Protective Measures: Eliminate all sources of ignition in vicinity of spilled material.

Spill Management: Stop the source of the release if you can do it without risk. Contain release to prevent further contamination of soil, surface water or groundwater. Clean up spill as soon as possible, observing precautions in Exposure Controls/Personal Protection. Use appropriate techniques such as applying non-combustible absorbent materials or pumping. Where feasible and appropriate, remove contaminated soil. Place contaminated materials in disposable containers and dispose of in a manner consistent with applicable regulations.

Reporting: Report spills to local authorities and/or the U.S. Coast Guard's National Response Center at (800) 424-8802 as appropriate or required.

SECTION 7 HANDLING AND STORAGE

Precautionary Measures: DO NOT USE IN HIGH PRESSURE SYSTEMS in the vicinity of flames, sparks and hot surfaces. Use only in well ventilated areas. Keep container closed.

Keep out of the reach of children.

General Handling Information: Avoid contaminating soil or releasing this material into sewage and drainage systems and bodies of water.

Static Hazard: Electrostatic charge may accumulate and create a hazardous condition when handling this

material. To minimize this hazard, bonding and grounding may be necessary but may not, by themselves, be sufficient. Review all operations which have the potential of generating and accumulating an electrostatic charge and/or a flammable atmosphere (including tank and container filling, splash filling, tank cleaning, sampling, gauging, switch loading, filtering, mixing, agitation, and vacuum truck operations) and use appropriate mitigating procedures. For more information, refer to OSHA Standard 29 CFR 1910.106, 'Flammable and Combustible Liquids', National Fire Protection Association (NFPA 77, 'Recommended Practice on Static Electricity', and/or the American Petroleum Institute (API) Recommended Practice 2003, 'Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents'.

Container Warnings: Container is not designed to contain pressure. Do not use pressure to empty container or it may rupture with explosive force. Empty containers retain product residue (solid, liquid, and/or vapor) and can be dangerous. Do not pressurize, cut, weld, braze, solder, drill, grind, or expose such containers to heat, flame, sparks, static electricity, or other sources of ignition. They may explode and cause injury or death. Empty containers should be completely drained, properly closed, and promptly returned to a drum reconditioner or disposed of properly.

SECTION 8 EXPOSURE CONTROLS/PERSONAL PROTECTION

GENERAL CONSIDERATIONS:

Consider the potential hazards of this material (see Section 3), applicable exposure limits, job activities, and other substances in the work place when designing engineering controls and selecting personal protective equipment. If engineering controls or work practices are not adequate to prevent exposure to harmful levels of this material, the personal protective equipment listed below is recommended. The user should read and understand all instructions and limitations supplied with the equipment since protection is usually provided for a limited time or under certain circumstances.

ENGINEERING CONTROLS:

Use in a well-ventilated area.

PERSONAL PROTECTIVE EQUIPMENT

Eye/Face Protection: No special eye protection is normally required. Where splashing is possible, wear safety glasses with side shields as a good safety practice.

Skin Protection: No special protective clothing is normally required. Where splashing is possible, select protective clothing depending on operations conducted, physical requirements and other substances in the workplace. Suggested materials for protective gloves include: 4H (PE/EVAL), Nitrile Rubber, Silver Shield, Viton.

Respiratory Protection: No respiratory protection is normally required.

If user operations generate an oil mist, determine if airborne concentrations are below the occupational exposure limit for mineral oil mist. If not, wear an approved respirator that provides adequate protection from the measured concentrations of this material. For air-purifying respirators use a particulate cartridge.

Use a positive pressure air-supplying respirator in circumstances where air-purifying respirators may not provide adequate protection.

Occupational Exposure Limits:

Component	Agency	TWA	STEL	Ceiling	Notation
Highly refined mineral oil (C15 - C50)	ACGIH	5 mg/m3	10 mg/m3	--	--
Highly refined mineral oil (C15 - C50)	OSHA Z-1	5 mg/m3	--	--	--

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Attention: the data below are typical values and do not constitute a specification.

Color: Varies depending on specification

Physical State: Liquid

Odor: Petroleum odor

pH: Not Applicable

Vapor Pressure: <0.01 mmHg @ 37.8 °C (100 °F)

Vapor Density (Air = 1): >1

Boiling Point: >315°C (599°F)

Solubility: Soluble in hydrocarbons; insoluble in water

Freezing Point: Not Applicable

Specific Gravity: 0.88 - 0.91 @ 15.6°C (60.1°F) / 15.6°C (60.1°F)

Density: 0.87 - 0.89 kg/l @ 15°C (59°F)

Viscosity: 6 - 26 mm2/s @ 100°C (212°F)

Evaporation Rate: No Data Available

SECTION 10 STABILITY AND REACTIVITY

Chemical Stability: This material is considered stable under normal ambient and anticipated storage and handling conditions of temperature and pressure.

Incompatibility With Other Materials: May react with strong acids or strong oxidizing agents, such as chlorates, nitrates, peroxides, etc.

Hazardous Decomposition Products: None known (None expected)

Hazardous Polymerization: Hazardous polymerization will not occur.

SECTION 11 TOXICOLOGICAL INFORMATION

IMMEDIATE HEALTH EFFECTS

Eye Irritation: The eye irritation hazard is based on evaluation of data for similar materials or product components.

Skin Irritation: The skin irritation hazard is based on evaluation of data for similar materials or product components.

Skin Sensitization: The skin sensitization hazard is based on evaluation of data for similar materials or product components.

Acute Dermal Toxicity: The acute dermal toxicity hazard is based on evaluation of data for similar materials or product components.

Acute Oral Toxicity: The acute oral toxicity hazard is based on evaluation of data for similar materials or product components.

Acute Inhalation Toxicity: The acute inhalation toxicity hazard is based on evaluation of data for similar materials or product components.

ADDITIONAL TOXICOLOGY INFORMATION:

This product contains petroleum base oils which may be refined by various processes including severe solvent extraction, severe hydrocracking, or severe hydrotreating. None of the oils requires a cancer warning under the OSHA Hazard Communication Standard (29 CFR 1910.1200). These oils have not been listed in the National Toxicology Program (NTP) Annual Report nor have they been classified by the International Agency for Research on Cancer (IARC) as; carcinogenic to humans (Group 1), probably carcinogenic to humans (Group 2A), or possibly carcinogenic to humans (Group 2B). These oils have not been classified by the American Conference of Governmental Industrial Hygienists (ACGIH) as: confirmed human carcinogen (A1), suspected human carcinogen (A2), or confirmed animal carcinogen with unknown relevance to humans (A3).

SECTION 12 ECOLOGICAL INFORMATION

ECOTOXICITY

This material is not expected to be harmful to aquatic organisms. The ecotoxicity hazard is based on an evaluation of data for the components or a similar material.

ENVIRONMENTAL FATE

Ready Biodegradability: This material is not expected to be readily biodegradable. The biodegradability of this material is based on an evaluation of data for the components or a similar material.

SECTION 13 DISPOSAL CONSIDERATIONS

Use material for its intended purpose or recycle if possible. Oil collection services are available for used oil recycling or disposal. Place contaminated materials in containers and dispose of in a manner consistent with applicable regulations. Contact your sales representative or local environmental or health authorities for approved disposal or recycling methods.

SECTION 14 TRANSPORT INFORMATION

The description shown may not apply to all shipping situations. Consult 49CFR, or appropriate Dangerous Goods Regulations, for additional description requirements (e.g., technical name) and mode-specific or quantity-specific shipping requirements.

DOT Shipping Description: PETROLEUM LUBRICATING OIL, NOT REGULATED AS A HAZARDOUS MATERIAL FOR TRANSPORTATION UNDER 49 CFR

Additional Information:NOT HAZARDOUS BY U.S. DOT. ADR/RID HAZARD CLASS NOT APPLICABLE.

IMO/IMDG Shipping Description: PETROLEUM LUBRICATING OIL; MAY BE REGULATED AS DANGEROUS GOODS FOR TRANSPORT UNDER THE IMDG CODE

ICAO/IATA Shipping Description: PETROLEUM LUBRICATING OIL; NOT REGULATED AS DANGEROUS GOODS FOR TRANSPORT UNDER ICAO TI OR IATA DGR

SECTION 15 REGULATORY INFORMATION

EPCRA 311/312 CATEGORIES: 1. Immediate (Acute) Health Effects: NO

2. Delayed (Chronic) Health Effects: NO

3. Fire Hazard: NO

4. Sudden Release of Pressure Hazard: NO

5. Reactivity Hazard: NO

REGULATORY LISTS SEARCHED:

01-1=IARC Group 1	03=EPCRA 313
01-2A=IARC Group 2A	04=CA Proposition 65
01-2B=IARC Group 2B	05=MA RTK
02=NTP Carcinogen	06=NJ RTK
	07=PA RTK

The following components of this material are found on the regulatory lists indicated.

Zinc alkyl dithiophosphate	03, 06

CHEMICAL INVENTORIES:

All components comply with the following chemical inventory requirements: AICS (Australia), DSL (Canada), EINECS (European Union), ENCS (Japan), IECSC (China), KECI (Korea), PICCS (Philippines), TSCA (United States).

NEW JERSEY RTK CLASSIFICATION:

Under the New Jersey Right-to-Know Act L. 1983 Chapter 315 N.J.S.A. 34:5A-1 et. seq., the product is to be

identified as follows: PETROLEUM OIL (Automatic transmission fluid)

WHMIS CLASSIFICATION:

This product is not considered a controlled product according to the criteria of the Canadian Controlled Products Regulations.

SECTION 16 OTHER INFORMATION

NFPA RATINGS: Health: 0 Flammability: 1 Reactivity: 0

HMIS RATINGS: Health: 1 Flammability: 1 Reactivity: 0

(0-Least, 1-Slight, 2-Moderate, 3-High, 4-Extreme, PPE:- Personal Protection Equipment Index recommendation, *- Chronic Effect Indicator). These values are obtained using the guidelines or published evaluations prepared by the National Fire Protection Association (NFPA) or the National Paint and Coating Association (for HMIS ratings).

LABEL RECOMMENDATION:

Label Category : INDUSTRIAL OIL 1 - IND1

REVISION STATEMENT: This revision updates the following sections of this Material Safety Data Sheet: 1,3,9,11,12,16.

Revision Date: March 13, 2009

ABBREVIATIONS THAT MAY HAVE BEEN USED IN THIS DOCUMENT:

TLV - Threshold Limit Value	TWA - Time Weighted Average
STEL - Short-term Exposure Limit	PEL - Permissible Exposure Limit
	CAS - Chemical Abstract Service Number
ACGIH - American Conference of Government Industrial Hygienists	IMO/IMDG - International Maritime Dangerous Goods Code
API - American Petroleum Institute	MSDS - Material Safety Data Sheet
CVX - Chevron	NFPA - National Fire Protection Association (USA)
DOT - Department of Transportation (USA)	NTP - National Toxicology Program (USA)
IARC - International Agency for Research on Cancer	OSHA - Occupational Safety and Health Administration

Prepared according to the OSHA Hazard Communication Standard (29 CFR 1910.1200) and the ANSI MSDS Standard (Z400.1) by the Chevron Energy Technology Company, 100 Chevron Way, Richmond, California 94802.

The above information is based on the data of which we are aware and is believed to be correct as of the date hereof. Since this information may be applied under conditions beyond our control and with which we may be unfamiliar and since data made available subsequent to the date hereof may suggest modifications of the information, we do not assume any responsibility for the results of its use. This information is furnished upon condition that the person receiving

it shall make his own determination of the suitability of the material for his particular purpose.

SDS: 0005716
Date Prepared: 01/30/2014

SAFETY DATA SHEET

1. IDENTIFICATION

Product Name:	**AEROFROTH® 76A Frother**
Synonyms:	Mixture
Chemical Family:	Alcohol
Molecular Formula:	Mixture
Molecular Weight:	Mixture
Intended/Recommended Use:	Mining chemical

CYTEC INDUSTRIES INC., FIVE GARRET MOUNTAIN PLAZA, WOODLAND PARK, NEW JERSEY 07424, USA
For Product and all Non-Emergency Information call 1-800/652-6013. Outside the USA and Canada call 1-973/357-3193.

EMERGENCY PHONE (24 hours/day) - For emergency only involving spill, leak, fire, exposure or accident call:
Asia Pacific:
Australia - +61-3-9663-2130 or 1800-033-111
China (PRC) - +86 0532 83889090 (NRCC)
New Guinea - +61-3-9663-2130
New Zealand - +61-3-9663-2130 or 0800-734-607
All Others - +65 3158 1074 (Carechem24 Singapore)
Canada: +1-905-356-8310 (Cytec Welland, Canada plant)
Europe/Africa/Middle East (Carechem24 UK):
Europe, Middle East, Africa, Israel - +44 (0) 1235 239 670
Middle East, Africa (Arabic speaking countries) - +44 (0) 1235 239 671
Latin America:
Brazil - 0800 7077 022 (SUATRANS)
Chile - +56-2-247-3600 (CITUC QUIMICO)
All Others - +52-376-73 74122 (Cytec Atequiza, Mexico plant)
USA: +1-703-527-3887 or 1-800-424-9300 (CHEMTREC #CCN6083)

The ® indicates a Registered Trademark in the United States and the ™ indicates a trademark in the United States. The mark may also be registered, subject of an application for registration, or a trademark in other countries.

2. HAZARDS IDENTIFICATION

GHS Classification
Flammable Liquid Hazard Category 4
Acute Toxicity (Inhalation) Hazard Category 4
Specific Target Organ Toxicity - Single Exposure Hazard Category 3
Skin Corrosion / Irritation Hazard Category 2
Serious Eye Damage / Eye Irritation Hazard Category 2A
Aquatic Environment Acute Hazard Category 2
Aquatic Environment Chronic Hazard Category 2

LABEL ELEMENTS



Signal Word
Warning

Hazard Statements
Combustible liquid
Harmful if inhaled
May cause respiratory irritation
Causes skin irritation
Causes serious eye irritation
Toxic to aquatic life with long lasting effects

Precautionary Statements
Keep away from heat/sparks/open flames/hot surfaces. - No smoking.
Wear protective gloves/protective clothing/eye protection/face protection.
Avoid breathing dust/fume/gas/mist/vapours/spray.
Use only outdoors or in a well-ventilated area.
Wash face, hands and any exposed skin thoroughly after handling.
Avoid release to the environment.
In case of fire: Use CO2, dry chemical, or foam for extinction.
IF INHALED: Remove person to fresh air and keep comfortable for breathing.
Call a POISON CENTER or doctor/physician if you feel unwell.
IF ON SKIN: Wash with plenty of soap and water.
Specific treatment (see supplemental first aid instructions on this label).
If skin irritation occurs: Get medical advice/attention.
Take off all contaminated clothing and wash it before reuse.
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
If eye irritation persists: Get medical advice/attention.
Store in a well-ventilated place. Keep cool.
Store in a well-ventilated place. Keep container tightly closed.
Store locked up.
Dispose of contents/container in accordance with local and national regulations.

Hazards Not Otherwise Classified (HNOC), Other Hazards
Not applicable

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3. COMPOSITION/INFORMATION ON INGREDIENTS

HAZARDOUS INGREDIENTS

Component / CAS No.	%	GHS Classification	Carcinogen
2-Ethylhexanol tails 68609-68-7	60-100	Skin Irrit. 2 (H315) Eye Irrit. 2A (H319) Aquatic Acute 2 (H401) Aquatic Chronic 2 (H411)	-
2-Ethylhexanol 104-76-7	30-60	Flam. Liq. 4 (H227) Acute Tox. 4 (H332) STOT SE 3 (H335) Skin Irrit. 2 (H315) Eye Irrit. 2A (H319)	-

The specific chemical identity and/or exact percentage of composition for one or more ingredients has been withheld as a trade secret.

Additional GHS classification or other information may be included in this section but has not been adopted by OSHA. See Section 16 for full text of H phrases.

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4. FIRST AID MEASURES

DESCRIPTION OF FIRST AID MEASURES

Eye Contact:
Rinse immediately with plenty of water for at least 15 minutes. Obtain medical advice if there are persistent symptoms.

Skin Contact:
Remove contaminated clothing and shoes without delay. Wash immediately with plenty of water. Do not reuse contaminated clothing without laundering. Get medical attention if pain or irritation persists after washing or if signs and symptoms of overexposure appear.

Ingestion:
If swallowed, call a physician immediately. Only induce vomiting at the instruction of a physician. Never give anything by mouth to an unconscious person.

Inhalation:
Remove to fresh air. If breathing is difficult, give oxygen. Obtain medical advice if there are persistent symptoms.

MOST IMPORTANT SYMPTOMS AND EFFECTS, BOTH ACUTE AND DELAYED

None known

INDICATION OF ANY IMMEDIATE MEDICAL ATTENTION AND SPECIAL TREATMENT NEEDS

Not applicable

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5. FIRE-FIGHTING MEASURES

Suitable Extinguishing Media:
Use water spray, alcohol foam, carbon dioxide or dry chemical to extinguish fires. Water stream may be ineffective.

Protective Equipment:
Firefighters, and others exposed, wear self-contained breathing apparatus. Wear full firefighting protective clothing. See MSDS Section 8 (Exposure Controls/Personal Protection).

Special Hazards:
Keep containers cool by spraying with water if exposed to fire.

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6. ACCIDENTAL RELEASE MEASURES

Personal precautions:
Where exposure level is known, wear approved respirator suitable for level of exposure. Where exposure level is not known, wear approved, positive pressure, self-contained respirator. In addition to the protective clothing/equipment in Section 8 (Exposure Controls/Personal Protection), wear impermeable boots.

Methods For Cleaning Up:
Remove sources of ignition. Cover spills with some inert absorbent material; sweep up and place in a waste disposal container. Flush spill area with water.

References to other sections:
See Sections 8 and 13 for additional information.

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7. HANDLING AND STORAGE

HANDLING

7. HANDLING AND STORAGE

Precautions: Avoid release to the environment. Keep away from heat, sparks and open flame. - No smoking. Wear protective gloves and eye/face protection. Use only outdoors or in a well-ventilated area. Wash hands thoroughly after handling. Avoid breathing vapors or spray mist.

Special Handling Statements: None

STORAGE
Areas containing this material should have fire safe practices and electrical equipment in accordance with applicable regulations and/or guidelines. Standards are primarily based on the material's flashpoint, but may also take into account properties such as miscibility with water or toxicity. All local and national regulations should be followed.
In the Americas, National Fire Protection Association (NFPA) 30: Flammable and Combustible Liquids Code, is a widely used standard. NFPA 30 establishes storage conditions for the following classes of materials: Class I Flammable Liquids, Flashpoint <37.8 °C. Class II Combustible Liquids, 37.8 °C < Flashpoint <60 °C. Class IIIa Combustible Liquids, 60 °C < Flashpoint < 93 °C. Class IIIb Combustible Liquids, Flashpoint > 93 °C.

Storage Temperature: Room temperature
Reason: Safety.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Engineering Measures:
Where this material is not used in a closed system, good enclosure and local exhaust ventilation should be provided to control exposure.

Respiratory Protection:
Where exposures are below the established exposure limit, no respiratory protection is required. Where exposures exceed the established exposure limit, use respiratory protection recommended for the material and level of exposure.

Eye Protection:
Wear eye/face protection such as chemical splash proof goggles or face shield. Eyewash equipment and safety shower should be provided in areas of potential exposure.

Skin Protection:
Avoid skin contact. Wear impermeable gloves and suitable protective clothing. Since this product is absorbed through the skin, care must be taken to prevent skin contact and contamination of clothing.

Hand Protection:
Wear impermeable gloves. Replace gloves immediately when torn or any change in appearance (dimension, colour, flexibility etc) is noticed. Barrier creams may help to protect the exposed areas of the skin, they should however not be applied once exposure has occurred.

Additional Advice:
Food, beverages, and tobacco products should not be carried, stored, or consumed where this material is in use. Before eating, drinking, or smoking, wash face and hands thoroughly with soap and water.

Exposure Limit(s)

No values have been established.

9. PHYSICAL AND CHEMICAL PROPERTIES

Color:	yellow-brown	
Appearance:	liquid	
Odor:	pungent	
Boiling Point:	101 - 299 °C	214 - 570.2 °F

9. PHYSICAL AND CHEMICAL PROPERTIES

Melting Point:	Not available		
/apor Pressure:	Not available		
Specific Gravity/Density:	0.83 - 0.92		
Vapor Density:	Not available		
Percent Volatile (% by wt.):	Not available		
pH:	Not available		
Saturation In Air (% By Vol.):	Not available		
Evaporation Rate:	Not available		
Solubility In Water:	Slight		
Volatile Organic Content:	Not available		
Flash Point:	81.7 °C	179 °F	Pensky-Martens Closed Cup
Flammable Limits (% By Vol):	Not available		
Autoignition Temperature:	Not available		
Decomposition Temperature:	Not applicable		
Partition coefficient (n-octanol/water):	Not available		
Odor Threshold:	Not available		
Viscosity (Kinematic):	Not available		

10. STABILITY AND REACTIVITY

Stability:	Stable
Conditions To Avoid:	None known
Polymerization:	Will not occur
Conditions To Avoid:	None known
Materials To Avoid:	Strong oxidizing agents. Strong acids
Hazardous Decomposition Products:	Carbon dioxide Carbon monoxide (CO)

11. TOXICOLOGICAL INFORMATION

PRODUCT TOXICITY INFORMATION

Likely Routes of Exposure: Eyes, Skin.

ACUTE TOXICITY DATA

oral	rat	Acute LD50	>2000 mg/kg
dermal	rabbit	Acute LD50	>2000 mg/kg
inhalation	rat	Acute LC50 4 hr	~3.7 mg/l (Dust/Mist)

LOCAL EFFECTS ON SKIN AND EYE

Acute Irritation	skin	Irritating
Acute Irritation	eye	Irritating

ALLERGIC SENSITIZATION

Sensitization	skin	Not sensitizing
Sensitization	respiratory	Not sensitizing

GENOTOXICITY

Assays for Gene Mutations
Ames Salmonella Assay No data

OTHER INFORMATION
The product toxicity information above has been estimated.

HAZARDOUS INGREDIENT TOXICITY DATA

2-Ethylhexanol tails have acute oral (rat) and acute dermal (rabbit) LD50 values of > 5000 mg/kg, respectively. Eye and skin irritation studies have shown this material to be moderately irritating in laboratory animals. Overexposure to vapor may cause irritation to the respiratory tract and eyes and may cause central nervous system effects.

2-Ethylhexanol (CAS# 104-76-7) has acute oral (rat) LD50 and acute dermal (rabbit) LD50 values of >2000 mg/kg. The 4-hour inhalation LC50 (rat) is > 0.89 but <= 5.3 mg/l (mixed vapor and aerosol). 2-Ethylhexanol is a moderate to severe eye and moderate skin irritant. Repeated skin exposure may cause skin dryness or cracking. Inhalation overexposure to 2-ethylhexanol may produce headache, dizziness, central nervous system depression possibly leading to unconsciousness and irritation of the eyes and respiratory tract. 2-Ethylhexanol is an aspiration hazard. Chronic overexposure to 2-ethylhexanol may cause liver damage, pulmonary edema, or renal damage with glycosuria. In a teratology study in rats 3 ml/kg applied to the skin during the most critical part of gestation produced evidence of maternal toxicity, but no evidence of injury to the offspring. In a separate study, fetal toxicity and an increased incidence of birth defects were noted when pregnant rats were administered 2 ml/kg by stomach tube during gestation. Ritter, et al (1987) reported teratological effects in rats following administration of 2-Ethylhexanol on day 12 gestation. Astill, et al (1996) found that 2-Ethylhexanol was not oncogenic in rats, and reported a weak association with hepatocellular carcinoma incidence in mice at a chronic dose of 750 mg/kg. Divencenzo, et al (1985) saw no evidence of mutagenic substances excreted in the urine of rats dosed with 2-Ethylhexanol. Agarwal, et al (1985) reported that 2-Ethylhexanol exhibited no mutagenicity in Salmonella typhimurium strains TA98, 100, 1535, 1537, 1538, and 2637, with or without S9 activation. 2-Ethylhexanol did exhibit a moderate cytotoxic effect in most cultures. 2-Ethylhexanol has caused toxic effects in the prostate and immune systems of laboratory animals.

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12. ECOLOGICAL INFORMATION

TOXICITY, PERSISTENCE AND DEGRADABILITY, BIOACCUMULATIVE POTENTIAL, MOBILITY IN SOIL, OTHER ADVERSE EFFECTS

Overall Environmental Toxicity: Toxic to aquatic life. Toxic to aquatic life with long lasting effects.

This material is not readily biodegradable.

FISH TEST RESULTS

Test: Acute toxicity, freshwater (OECD 203)
Duration: 96 hr. **Procedure:** Static.
Species: Rainbow Trout (Oncorhyncus mykiss)
21.7 mg/l LC50

INVERTEBRATE TEST RESULTS

Test: Acute Immobilization (OECD 202)
Duration: 48 hr **Procedure:** Static
Species: Water Flea (Daphnia magna)
4.6 mg/l EC50

DEGRADATION

Test: CO2 Evolution: Modified Sturm (OECD 301B)
Duration: 28 day **Procedure:** Ready biodegradability
40 %

RESULTS OF PBT AND vPvB ASSESSMENT
Not determined

HAZARDOUS INGREDIENT TOXICITY DATA

Component / CAS No.	Toxicity to Algae	Toxicity to Fish	Toxicity to Water Flea
2-Ethylhexanol tails 68609-68-7	Not available	LC50 = 50 mg/L - Brachydanio rerio (96h)	Not available
2-Ethylhexanol 104-76-7	EC50 = 11.5 mg/L - Desmodesmus subspicatus (72h)	LC50 27 - 29.5 mg/L - Pimephales promelas (96h) LC50 32 - 37 mg/L - Oncorhynchus mykiss (96h) LC50 10.0 - 33.0 mg/L - Lepomis macrochirus (96h) LC50 = 29.7 mg/L - Pimephales promelas (96h) LC50 > 7.5 mg/L - Oncorhynchus mykiss (96h)	EC50 = 39 mg/L - Daphnia magna (48h)

13. DISPOSAL CONSIDERATIONS

The information on RCRA waste classification and disposal methodology provided below applies only to the product, as supplied. If the material has been altered or contaminated, or it has exceeded its recommended shelf life, the guidance may be inapplicable. Hazardous waste classification under federal regulations (40 CFR Part 261 et seq) is dependent upon whether a material is a RCRA "listed hazardous waste" or has any of the four RCRA "hazardous waste characteristics." Refer to 40 CFR Part 261.33 to determine if a given material to be disposed of is a RCRA "listed hazardous waste"; information contained in Section 15 of this MSDS is not intended to indicate if the product is a "listed hazardous waste." RCRA Hazardous Waste Characteristics: There are four characteristics defined in 40 CFR Section 261.21-61.24: Ignitability, Corrosivity, Reactivity, and Toxicity. To determine Ignitability, see Section 9 of this MSDS (flash point). For Corrosivity, see Sections 9 and 14 (pH and DOT corrosivity). For Reactivity, see Section 10 (incompatible materials). For Toxicity, see Section 3 (composition). Federal regulations are subject to change. State and local requirements, which may differ from or be more stringent than the federal regulations, may also apply to the classification of the material if it is to be disposed. The Company encourages the recycle, recovery and reuse of materials, where permitted, as an alternate to disposal as a waste. The Company recommends that organic materials classified as RCRA hazardous wastes be disposed of by thermal treatment or incineration at EPA approved facilities. The Company has provided the foregoing for information only; the person generating the waste is responsible for determining the waste classification and disposal method.

14. TRANSPORT INFORMATION

This section provides basic shipping classification information. Refer to appropriate transportation regulations for specific requirements.

US DOT

Dangerous Goods? X
Proper Shipping Name: Combustible liquid, n.o.s.
Hazard Class: Combustible liquid
Packing Group: III
UN/ID Number: NA1993
Transport Label Required: Marine Pollutant
Marine Pollutant
Technical Name (N.O.S.): Contains 2-ethylhexanol tails

Comments: Marine Pollutants - DOT requirements specific to Marine Pollutants do not apply to non-bulk packagings transported by motor vehicles, rail cars or aircraft. Combustible liquids are not regulated in non-bulk packagings unless the combustible liquid is a hazardous substance, a hazardous waste, or a marine pollutant.

TRANSPORT CANADA

Dangerous Goods? X
Proper Shipping Name: Environmentally hazardous substance, liquid, n.o.s.
Hazard Class: 9
Packing Group: III
UN Number: UN3082
Transport Label Required: Miscellaneous
Marine Pollutant
Marine Pollutant
Technical Name (N.O.S.): Contains 2-ethylhexanol tails

ICAO / IATA

Dangerous Goods? X
Proper Shipping Name: Environmentally hazardous substance, liquid, n.o.s.
Hazard Class: 9
Packing Group: III
UN Number: UN3082
Transport Label Required: Miscellaneous
Technical Name (N.O.S.): Contains 2-ethylhexanol tails

IMO

Dangerous Goods? X
Proper Shipping Name: Environmentally hazardous substance, liquid, n.o.s.
Hazard Class: 9
UN Number: UN3082
Packing Group: III
Transport Label Required: Miscellaneous
Marine Pollutant
Marine Pollutant
Technical Name (N.O.S.): Contains 2-ethylhexanol tails

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15. REGULATORY INFORMATION

15. REGULATORY INFORMATION

Inventory Information

United States (USA): All components of this product are included on the TSCA Chemical Inventory or are not required to be listed on the TSCA Chemical Inventory.

Canada: All components of this product are included on the Domestic Substances List (DSL) or are not required to be listed on the DSL.

Australia: All components of this product are included in the Australian Inventory of Chemical Substances (AICS) or are not required to be listed on AICS.

China: All components of this product are included on the Chinese inventory or are not required to be listed on the Chinese inventory.

Japan: All components of this product are included on the Japanese (ENCS) inventory or are not required to be listed on the Japanese inventory.

Korea: All components of this product are included on the Korean (ECL) inventory or are not required to be listed on the Korean inventory.

Philippines: One or more components of this product are NOT included on the Philippine (PICCS) inventory.

OTHER ENVIRONMENTAL INFORMATION

The following components of this product may be subject to reporting requirements pursuant to Section 313 of CERCLA (40 CFR 372), Section 12(b) of TSCA, or may be subject to release reporting requirements (40 CFR 307, 40 CFR 311, etc.) See Section 13 for information on waste classification and waste disposal of this product.

This product does not contain any components regulated under these sections of the EPA

PRODUCT HAZARD CLASSIFICATION UNDER SECTION 311 OF SARA

- Acute
- Fire

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16. OTHER INFORMATION

NFPA Hazard Rating (National Fire Protection Association)

Health: 2 - Materials that, under emergency conditions, can cause temporary incapacitation or residual injury.

Fire: 2 - Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur.

Instability: 0 - Materials that in themselves are normally stable, even under fire exposure conditions.

Reasons For Issue: Revised Section 3
Revised Section 8
Revised Section 11
Revised Section 14
Revised Section 15

Date Prepared: 01/30/2014
Date of last significant revision: 01/30/2014

Component Hazard Phrases
2-Ethylhexanol tails

H315 - Causes skin irritation.
H319 - Causes serious eye irritation.
H411 - Toxic to aquatic life with long lasting effects.

2-Ethylhexanol

H227 - Combustible liquid.
H315 - Causes skin irritation.
H319 - Causes serious eye irritation.
H332 - Harmful if inhaled.
H335 - May cause respiratory irritation.

Prepared By: Legal & Compliance Services; E-mail: custinfo@cytec.com

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