STATE OF NEW MEXICO
BEFORE THE WATER QUALITY CONTROL COMMISSION

In the Matter of:	)	
	)	
PROPOSED AMENDMENT TO 20.6.2 NMAC (Copper Rule)	)	**No. WQCC 12-01(R)**

WRITTEN TESTIMONY OF JIM B. FINLEY JR.

I. INTRODUCTION

My name is Jim Barton Finley Jr. I am providing testimony regarding the proposed Copper Mine Rule, which is set forth in the New Mexico Environment Department's (NMED) Petition in this matter dated October 30, 2012. Specifically, my testimony on the Proposed Rule will focus on two topics covered by the Rule: (1) Waste Rock Stockpiles (20.6.7.21 NMAC) and (2) Open Pits (20.6.7.24 NMAC).

I am qualified to give this written testimony based upon by educational background and professional experience. I obtained a Bachelor of Science in Forestry from the University of Montana in 1979; a Master's of Science in Earth Resources from Colorado State University in 1984; and a Doctor of Philosophy in Geology from the University of Wyoming in 1993. Throughout my post-secondary training, my academic focus was in the field of low-temperature (*i.e.*, Earth's surface) geochemistry within the discipline of geology. My research for the Ph.D. was investigating water-rock interactions occurring in a snowmelt dominated, high elevation catchment. I also studied ground water hydrology while working on my Master's and Ph.D.

After receiving my Ph.D. in 1993, I taught in the Department of Geology at Miami University in Oxford, Ohio from the Fall of 1993 until the Spring of 1996. I have worked as a consultant since the Fall of 1996, beginning at Shepherd-Miller, Inc. in Fort Collins, Colorado through my current work at Telesto Solutions Incorporated. I have attached my current Curriculum Vitae as Exhibit Finley-1.

The focus of my professional work remains low-temperature geochemistry, but the specifics have changed from high-elevation, snowmelt dominated systems to hard rock mining systems, principally in the western United States. I have worked on geochemical issues related to sulfide hosted ore systems in Colorado, New Mexico, Arizona, Nevada, Idaho, and Montana. I have worked at copper mines in New Mexico and Arizona since approximately 1997. Much of my work has been on copper mines in Arizona. However, the porphyry copper deposits and related geochemistry of southern Arizona are similar to the porphyry copper deposits in New Mexico. Large-scale geologic processes, such as the porphyry copper deposits of the southwestern United States are opaque to state boundaries. That is, the geochemical issues at copper mines in New Mexico are similar to the geochemical issues faced by copper mines in Arizona.

My written testimony incorporates the language of the Proposed Rule from Attachment 1 to NMED's Petition dated October 30, 2012. This language is incorporated into my testimony for ease of reference, and so that if any changes to the Proposed Rule are considered by the Water Quality Control Commission (WQCC), the record is clear regarding the exact language to which my testimony applies.

II. WASTE ROCK STOCKPILES (20.6.7.21 NMAC)

The Proposed Rule sets forth detailed requirements for Waste Rock Stockpiles in 20.6.7.21 NMAC. In order to understand these requirements, one must first understand what "waste rock" means for purposes of the Proposed Rule, which defines the term as follows:

> **20.6.7.7 DEFINITIONS:**
>
> A. Terms defined in the Water Quality Act and 20.6.2.7 NMAC shall have the meanings as given in such.
> B. A term defined in this part shall have the following meaning.
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> . . . .
>
> (62) "Waste rock" means all material excavated from a copper mine facility that is not ore or clean top soil.

This definition is consistent with the academic and professional definition of "waste rock." Mineralized copper deposits are often formed by circulating water that interacts with geologic materials creating areas, or zones, where the concentration of certain elements (including copper) is higher than the concentration outside the zone of circulation. The nature and extent of the zone depends on specific geologic conditions at a given geographic location.

When an exploration program identifies the zones of higher elemental concentrations, and when the concentrations meet specific economic criteria, the concept of an ore body is developed. The shape of the ore body in hard rock mines is determined by the economics of the extraction process and market conditions for the ultimate mine plan. As a consequence of the geologic formation of ore bodies, and the fact that the starting location for all extraction activities is the Earth's surface, most of the time there is the need to remove other geologic materials before gaining access to the ore body. Because the ore body is defined not by the presence/absence of an element, but rather by the economics of extraction/production/sale at the time, there will also be geologic materials extracted that will contain the element of interest (*e.g.*, copper), but that the concentration is too low at the time of extraction to allow economic processing of the material. Furthermore, there are only very rare occasions where the geologic deposit contains only the element of interest. Rather, because of similar geochemical properties, the mineralization includes a broad variety of chemical elements and associated compounds whose concentrations within the mineralized zone do not necessarily follow the target chemical element. As a result, there is a zone around the ore body that contains elements and compounds that are potential contaminants, and this material requires special handling during the mining operation and constitutes the need for a definition of "waste rock." All geologic material extracted prior to intersecting the ore body is referred to as waste rock. The Proposed Rule's definition of "waste rock" is consistent with the fundamental geology associated with mineralized copper deposits in New Mexico.

The Proposed Rule contains specific requirements for copper mine waste rock stockpiles, which begins as follows:

> **20.6.7.21 REQUIREMENTS FOR COPPER MINE WASTE ROCK STOCKPILES**
>
> **A. Material characterization requirements**:
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> (1) **Material characterization and acid mine drainage prediction.** All waste rock stored, deposited or disposed of at a copper mine facility shall be evaluated for its potential to generate acid and to release water contaminants at levels in excess of the standards of 20.6.2.3103 NMAC. A plan for determining the potential of the material to release water contaminants, and the method for such evaluations shall be submitted to the department for approval in a material characterization plan that includes: . . .

It is my opinion that these requirements are appropriate based upon my academic training and professional experience. Waste rock that is placed in a stockpile is subject to exposure to atmospheric conditions, including contact with precipitation and atmospheric gases, primarily oxygen. If the waste rock contains sulfide minerals (*e.g.*, iron sulfide), then geochemical reactions will occur that result in chemical weathering of the sulfide mineral. A portion of the chemical weathering product is water soluble and can be dissolved in and transported by infiltrating precipitation. If there is limited sulfide minerals in the waste rock, there may still be constituents that can be dissolved in water that may result in elevated concentrations. Both chemical weathering and chemical availability due to production of waste rock serve as the source for leachate that is generated from a waste rock stockpile when precipitation flows through and contacts waste rock.

Typical constituents contained in waste rock leachate from copper mines include: manganese (Mn), iron (Fe), copper (Cu), arsenic (As), zinc (Zn), sulfate (SO_4), and fluoride (F). Concentrations can range as follow:

Metals (Mn, Fe, Zn, Cd):	.001 to 100s milligrams per liter (mg/L)
Metalloids (As):	.001 to 1 mg/L
Anions (SO_4, F):	.01 to 1,000s mg/L

Experience of the copper mining industry suggests, *a priori*, that waste rock associated with copper mines in New Mexico will produce leachate containing constituents that are not commonly found in surface or ground water in non-mineralized areas. Thus, there is need to characterize the geochemical properties of the waste rock to determine the types and potential concentrations of constituents that could be released during chemical weathering of waste rock.

Development of a waste rock characterization plan is a component of any copper mine plan, and it is essential for evaluating and predicting the geochemical composition of leachate produced by waste rock stockpiles. As with any type of characterization plan in which measurements are made, there is need to assure that the measured results are indicative of the processes of interest and not due to an aspect of the test or measurement. This need is the basis for including Quality Assurance and Quality Control (QA/QC) protocols in the waste rock characterization plan.

In 20.6.7.21.A(1) NMAC, materials characterization plan must meet the following criteria:

A. Material characterization requirements:

(1) **Material characterization and acid mine drainage prediction.** All waste rock stored, deposited or disposed of at a copper mine facility shall be evaluated for its potential to generate acid and to release water contaminants at levels in excess of the standards of 20.6.2.3103 NMAC. A plan for determining the potential of the material to release water contaminants, and the method for such evaluations shall be submitted to the department for approval in a material characterization plan that includes:

(a) The geologic, mineralogic, physical, and geochemical characteristics of the material stored, deposited or disposed of at the copper mine facility.

(b) A sampling and analysis plan to provide representative samples of the entire range of material stored, deposited or disposed of at the copper mine facility. The plan shall include quality assurance/quality control procedures to be implemented to ensure the validity of the sample results. The plan shall consider the following factors in collecting and establishing representative samples:

(i) lithological variations;

(ii) particle size distribution of each lithology;

(iii) hydraulic conductivity, water content or matric suction relationship for each lithology;

(iv) mineralogical and textural variations;

(v) the nature and extent of sulfide mineralization;

(vi) color variation;

(vii) degree and nature of fracturing;

(viii) variations in oxidation and reducing conditions; and

(ix) the nature and extent of secondary mineralization.

(c) A static testing program using, at a minimum, acid/base accounting, or a department approved equivalent testing method, to evaluate the acid generation and neutralization potential of the material; and meteoric water mobility procedure or other department approved method for whole rock testing to determine water contaminant leaching potential.

(d) If the results of static testing indicate that a material may be acid generating or may generate a leachate containing water contaminants, a kinetic testing program to evaluate reaction rates, provide data to estimate drainage quality, the lag time to acidification of the material, and primary weathering and secondary mineral precipitation/dissolution as it may affect acidification, neutralization and drainage quality. The length of and/or means of determining when kinetic tests will be discontinued shall be approved by the department prior to implementation of the kinetic testing program. If a liner system is proposed for storage or disposal of waste rock pursuant to Subparagraph (d) of Paragraph (1) of Subsection B of this Section, a kinetic testing program is not required.

Based upon my professional experience, these are appropriate requirements for material characterization plans. Part of the challenge in materials characterization is that waste rock sampled *in situ* (via drill core sampling or other *in situ* method) is reflective of conditions where the rock, and associated minerals, has been and not where the rock and associated minerals will be. Further, *in situ* sampling yields materials that reflect the combined effects of geologic and hydrologic processes active since the origin of mineralization and initiation of chemical weathering. The action of excavating waste rock changes the physical properties of the material mainly because the action of blasting, loading, hauling, and stockpiling creates a myriad of grain sizes ranging from boulders to fine sand. The combined effects of creating waste rock result in the need to develop a sampling and analysis plan that addresses the geologic, mineralogic, geochemical, and hydraulic properties of waste rock. Furthermore, there is a need to characterize the hydrologic and geochemical properties each of the lithologies that will be present in the waste rock stockpile.

The items identified in 20.6.7.21.A(1)(b) NMAC are all pertinent topics to address in gathering information about waste rock. The collective information provides the basis for making reasonable and technically defensible predictions of leachate water chemistry that will emanate from the waste rock stockpile. Furthermore, the information also allows planners (*i.e.*, engineers and scientists) the basic information needed to design the waste rock stockpile in such a way as to limit generation and release of constituents from the waste rock mineralogy.

Most of the topics identified in 20.6.7.21.A(1)(b) NMAC would be addressed by compiling well log information gathered by a qualified geologist during exploration drilling either by inspection of drill cuttings or evaluation of drill core. Lithology, mineralogy (and texture), nature and extent of sulfide mineralization, color variation, degree and nature of fracturing, variation in oxidation and reducing conditions, alteration, and nature and extent of secondary mineralization are all visual observations. Additional evaluation of mineralogy can be completed using either optical microscopy (with thin sections), x-ray diffractometry (XRD), scanning electron microscopy (SEM), and/or electron probe micro-analysis (EPMA).

While visual observations of the "nature and extent of sulfide mineralization" is helpful in categorizing waste rock at a low resolution in terms of ability to predict reactivity of sulfides in a waste rock stockpile, a more detailed mineralogic investigation provides important information about specific characteristics of sulfide(s) present. Identifying the specific sulfide minerals present and their relative abundance is important because the reactivity of sulfide minerals varies sufficiently that the potential of waste rock to produce leachate that could impact ground water quality depends on the sulfide minerals present. Alpers and Nordstrom (1999), which is attached as Exhibit Finley-2. Additionally, the degree to which the sulfide minerals are encapsulated also affect the overall reactivity due to a decrease in the surface area of mineral available for interaction with water and air.

In addition to sampling and analysis of waste rock, 20.6.7.21.A(1) NMAC also calls for a geochemical testing program that presents a staged approach to answering the questions: (1) will the waste rock produce acid rock drainage and (2) what is the chemical composition of leachate produced by the waste rock. The industry, with a large body of research from industry, agencies, and universities, has recognized a suite of laboratory tests that have proven to provide a good indication of geochemical properties that address the two previously stated questions. *See* GARD Guide, which is attached as Exhibit Finley-3. Acid-base accounting (ABA) is a static laboratory test that considers the balance of acid generating potential and acid neutralizing potential based on measurements of sulfur and acid buffering capacity. One main assumption in the ABA determination is that iron sulfide is the primary sulfide mineral in the sample, and the resulting calculation of acid generating potential reflects the specific chemical weathering formula for iron sulfide. The potential range of sulfide minerals present (*i.e.*, not iron sulfide) is another good reason for careful determination of sulfide mineral distribution in the waste rock.

The resulting acid generating potential (AGP) and acid neutralizing potential (ANP) are interpreted based on the following metrics obtained using AGP and ANP (GARD Guide, BLM). The ratio of ANP to AGP, or neutralization potential ratio (NPR), is one measure of the potential for waste rock to generate acid rock drainage. Net neutralization potential (NNP) is calculated as the difference between ANP and AGP in units of tons equivalent calcium carbonate ($CaCO_3$) per kiloton of waste rock. Typical criteria for identifying potentially acid generating material using the aforementioned metrics are (Morin and Hutt, 1997; White, *et al.*, 1999, which are attached as Exhibits Finley-4 & 5, respectfully):

Acid Generating:	NNP < 0; NPR < 1
Uncertain:	$0 <$ NNP $< +20$; $1<$ NPR < 3
Non-Acid:	NNP > 20; NPR > 3

There are many variants of this classification and other static tests that have been used in place of, or in addition to, ABA (*see* GARD Guide), but the key point in this example, and for any variant, is that there are waste rock that will undoubtedly generate acidic leachate, other waste rock that will NEVER generate acidic leachate, and a final group of waste rock for which the ABA yields uncertain results.

There are, as with any laboratory geochemical test procedure, a myriad of factors that can affect the results of an ABA determination. *See* GARD Guide. The original intent of kinetic testing, which is the second level of geochemical testing to answer the question of “Will it go acid?", was to create conditions that maximize the oxidation of sulfide minerals regardless of their mineral habit (*e.g.*, cubic or framboidal), degree of encapsulation, or abundance. A kinetic leach test is set up to ensure ready access to oxygen and water to enhance chemical oxidation of sulfide minerals and to accelerate the oxidation process. Subsequently, there was recognition that the kinetic test provided a means to also extract estimates of: (1) mineral reaction rates, (2) lag time to acidification, (3) reaction mineralogy, and (4) leachate chemistry. Thus, when ABA, or other acceptable static test yields results that indicate uncertainty in the acid drainage potential of waste rock a kinetic testing program is used to answer the question (*i.e.*, will it go acid).

The geochemical test procedures outlined in 20.6.7.21.A(1) NMAC are consistent with the current standard of practice in the United States and elsewhere. Review of the geochemical testing program employed at other mines (*e.g.*, the phoenix mine, battle mountain, nevada) shows a similar framework for waste rock characterization. The GARD Guide discusses the basis and foundation for a similar geochemical testing program to identify the potential for waste rock leachate to become acidic and for the leachate to contain constituents that could impact ground water.

Naturally occurring geological processes result in the deposition and formation of rocks that contain sulfur-bearing (mainly as a sulfide) minerals, with iron sulfide being the best known mineral. When the geologic deposit is exposed to atmospheric conditions, the sulfide minerals chemically weathering by oxidation with the result that water contacting the weathered sulfides is acidic, metal-bearing, and has elevated concentrations of sulfate. When this process occurs naturally, the resulting drainage is referred to as *acid rock drainage*. When said process occurs in a mining setting, the drainage is referred to as *acid mine drainage*. To define water as acidic depends on the context of the situation. That is, in a pure theoretical context, such as one would find in any text addressing introductory inorganic chemistry, any pH condition less than 7 is acidic. In this case, the water is pure containing only hydronium and hydroxide, which serve as the sole source of acidity and alkalinity, respectively.

In natural environments, for example where copper mines occur, precipitation is the source of water that interacts with waste rock. At the fundamental level, the pH of rain water is defined as pure water in equilibrium with atmospheric carbon dioxide gas. *See* Drever, 1997, which is attached as Exhibit Finley-5. Atmospheric water in chemical equilibrium with atmospheric carbon dioxide gas has a pH of 5.66 at an atmospheric carbon dioxide concentration of 316 parts per million (ppm). At an atmospheric concentration of 398 ppm, the pH of pure atmospheric water would be 5.6. The ultimate pH of precipitation (mainly speaking of rain) is the balance between cations (*e.g.*, calcium, magnesium, sodium, and potassium) and anions (carbonate/bicarbonate, sulfate, nitrate, and chloride). Acid rain derives from an excess of sulfur and nitrogen compounds that are not balanced by the major cations listed previously. When precipitation interacts with geologic materials, natural or related to copper mining, the interaction of the water with the rocks and minerals influences the balance of cations and anions. Then, the pH of water that contacts chemically inert geologic material, such as pure silica (*e.g.*, quartz), will remain the same as the rain water. In almost all other conditions and environments, there is some level of geochemical reactions between rain water and geologic materials at the land surface, with the result that the pH of water after interaction with the geologic materials is not the same as the pH of rain water.

The term "acid mine drainage" is defined in the Proposed Rule as follows:

20.6.7.7 DEFINITIONS:

A. Terms defined in the Water Quality Act and 20.6.2.7 NMAC shall have the meanings as given in such.

B. A term defined in this part shall have the following meaning.

(1) "Acid mine drainage" means water that is discharged from an area affected by mining exploration, mining, or reclamation, with a pH of less than 5.5 and in which total acidity exceeds total alkalinity as defined by the latest edition of *standard methods for the examination of water and wastewater*.

Based upon the foregoing, this operational definition of acid mine drainage with pH less than 5.5 is reasonable and founded on sound technical reasoning. The portion of the definition of acid rock drainage that refers to metal- and sulfate-bearing is more specific to systems/environments where sulfide minerals are exposed to Earth surface conditions and chemical oxidation occurs. The GARD Guide provides an excellent summary of the relationship between pH, metals concentrations, and sulfate concentrations for acid rock/acid mine drainage. *See* Section 2.4.1, http://www.gardguide.com/index.php/Chapter_2#2.4_The_Acid_Generation_Process. This portion of the definition is also reasonable and based on sound technical reasoning.

A copper mining operation will generate waste rock and the waste rock generated will have to be placed in a stockpile that will become part of the environment. Identification of waste rock properties (physical and geochemical) provides basic information necessary to develop a plan to limit the potential for leachate draining from the waste rock stockpile to impact ground water quality. Such a plan is referred to as a material handling plan. The Proposed Rule contains the following requirements for material handling plans in 20.6.7.21(A)(2) NMAC:

> (2) **Material handling plan.** A permittee shall manage waste rock that may generate or release water contaminants according to a material handling plan approved by the department. The material handling plan shall address:
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> (a) segregation of acid generating materials and materials that may generate or release water contaminants and the method for handling, storage or disposal of the materials in a manner designed to prevent an exceedance of applicable standards;
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> (b) stockpiling of non-acid generating materials for potential use in neutralizing acid generating materials or in reclamation;
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> (c) blending or layering of material types to maximize the benefit of acid neutralizing material;
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> (d) disposal of all material types; and
>
> (e) any chemical amendments of the waste rock.
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> (f) If the results of the static testing or kinetic testing indicate that the material will be acid generating and the materials will be placed outside of an open pit surface drainage area, a plan shall be submitted to the department to evaluate whether discharges of leachate from the stockpile may cause an exceedance of applicable standards, including an evaluation of the geologic and hydrologic area where the material is to be stored. The plan shall include either a department approved model or a monitored, large scale field testing program.

The objective of the material handling plan is to provide the mining operation with directions as to how the waste rock stockpile should be built to maximize the benefits of waste rock with excess acid neutralizing potential and minimize, or limit, the effects of waste rock with acid generating potential. Based upon my professional experiences, these requirements in the Proposed Rule are appropriate and reasonable.

The Proposed Rule contains the following detailed engineering design requirements for new waste rock stockpiles:

> **B. Engineering design requirements for new waste rock stockpiles.** The following requirements shall be met in designing engineered structures for waste rock stockpiles at copper mine facilities that may generate water contaminants or acid mine drainage that may cause an exceedance of applicable standards, as determined through implementation of a material characterization and handling plan pursuant to Subsection A of 20.6.7.21 NMAC.
>
> (1) **New waste rock stockpiles located outside an open pit surface drainage area.** New waste rock stockpiles located outside an open pit surface drainage area shall meet the following requirements unless the department determines that deposition of waste rock, in accordance with an approved material handling plan prepared pursuant to Paragraph (2) of Subsection A of this Section, will not cause an exceedance of applicable standards.
>
> (a) Stormwater run-on shall be diverted or contained to minimize contact between precipitation run-on and the stockpiled material. The permittee shall prepare an engineering plan to limit the contact of run-on and stormwater with any materials that have the potential to generate water contaminants. The plan shall include, as necessary, design, construction, and installation of run-on, run-off, and stormwater diversion structures, collection of stormwater containing water contaminants, and a description of existing surface water drainage conditions. The plan shall consider:
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> (i) the amount, intensity, duration and frequency of precipitation;

(ii) watershed characteristics including the area, topography, geomorphology, soils and vegetation of the watershed; and

(iii) runoff characteristics including the peak rate, volumes and time distribution of runoff events.

(b) Drainage from the base of the waste rock stockpile shall be collected by headwalls keyed to bedrock, where applicable, and contained in impoundments located outside the open pit surface drainage area to be lined consistent with the requirements for containment of impacted stormwater.

(c) Interceptor wells or other measures to reduce, attenuate or contain the discharge of leachate that may cause ground water to exceed applicable standards shall be installed and operated where applicable.

(d) If the permittee or the department determines that, with the measures described in Paragraphs (a) through (c) of this Subsection, discharges of leachate from a stockpile located outside of the open pit surface drainage area would cause ground water to exceed applicable standards at a monitoring well located pursuant to 20.6.7.28 NMAC, the permittee may propose, or the department may require as an additional condition in accordance with Subsection I of 20.6.7.10 NMAC, additional controls, including but not limited to, a liner system.

(2) **New waste rock stockpiles located inside an open pit surface drainage area.** Stormwater run-on shall be diverted or contained to minimize contact between stormwater run-on and the stockpiled material.

Based upon my professional experiences, these are appropriate engineering design requirements for new waste stockpiles. There are several issues reasons that these requirements are appropriate and reasonable.

It is worth noting that there is no explicit discussion in the Proposed Rule (20.6.7 NMAC) of waste rock stockpiles that will not generate drainage leachate leading to ground water chemistry that exceeds the WQCC's ground water quality standards. There is reference, however, to that section of NMAC that does address waste rock stockpiles that will not generate leachate exceeding WQCC ground water standards. *See* 20.6.7.6 NMAC; 20.6.7.21.B(1) NMAC.

Control and capture of waste rock stockpile leachate that contains constituents at concentrations that would exceed ground water quality standards is technically challenging. The challenge is principally a hydrology issue in that the nature of leachate drainage depends on a combination of the climatic regime (*i.e.*, controlling the amount of precipitation input to the waste rock stockpile) and the hydraulic properties of the waste rock and underlying native materials. In most copper mine settings in New Mexico, the climatic and hydrologic regime results in an upper zone (10s to 100s of feet thick) that is unsaturated (*i.e.*, contains moisture, but pore spaces are not filled completely with water), with a saturated zone. Capturing or controlling unsaturated flow is very challenging in that diverting unsaturated flow, either by placing a cutoff/headwall or by installing ground water pumping wells relies on the presence of a discontinuity in vertical hydraulic conductivity that is sufficiently large enough to cause saturation. Under those conditions, placement of a headwall keyed to bedrock as described in 20.6.7.21.B(1)(b) NMAC will accomplish the objective of intercepting drainage from the base of a waste rock stockpile. Additional measures, such as interceptor wells, have also been used to reduce, attenuate, and contain waste rock stockpile leachate in saturated conditions.

A waste rock stockpile can receive water either by run-on from areas up gradient of the stockpile or by direct precipitation to the stockpile. Run-on is managed through standard stormwater controls that divert the upland flow from storm events so that the water does not contact or flow through the waste rock stockpile. Direct precipitation either infiltrates the waste rock stockpile or runoffs at the surface depending on the nature and extent of a given precipitation event and the hydraulic properties of the waste rock. The portion of direct precipitation that infiltrates can either remain in the waste rock stockpile as stored water, evaporates into the atmosphere, or can percolate through the waste rock stockpile. Stormwater runoff that contains constituents from waste rock is captured and may be stored before being incorporated into the mine water system. The goal of water management plans for waste rock stockpiles, and copper mines in general, is to limit, to the extent practicable, the amount of stormwater contacting mine materials, including waste rock.

In the Proposed Rule, the requirements differ markedly for waste rock stockpiles located inside the drainage area of an open pit versus a waste rock stockpile located outside the drainage area of an open pit. The reason for the difference is that a flow emanating from a waste rock stockpile located inside the drainage area of an open pit will ultimately report to the open pit or its water management system with no potential for impact to surface or ground water. In contrast, water flows from waste rock stockpiles that are located outside the drainage area of an open pit can, if not controlled, impact surface or ground water.

The measures listed in the Proposed Rule to control leachate from waste rock stockpiles affect control in two ways. Diversion of water, be it direct precipitation (*e.g.*, placing a cover) or run-on of upland stormwater, serves to limit the amount of water input to the waste rock stockpile. Once water is in the waste rock stockpile, there is not much that can be done to control or influence the contact of percolating water with waste rock. The other leachate control measures identified in the Proposed Rule addresses controls that can be emplaced to capture leachate after the water leaves the waste rock stockpile as saturated horizontal flow. Headwalls keyed into bedrock physically block the flow of waste rock stockpile leachate. Interceptor wells are designed to capture flow of waste rock stockpile leachate reaching the zone of influence imparted by the interceptor well field. The effectiveness of waste rock stockpile leachate control is determined by results of ground water samples collected at ground water monitoring wells placed as per 20.6.7.28 NMAC.

In my experience in the hard rock mining industry, there is currently no waste rock stockpiles placed on a liner. I am familiar with smaller tailings basins that are lined. As for the technical practicability of lining a waste rock stockpile, most all things are technically possible, but achieving the goal or objective of waste rock stockpile leachate drainage is the ultimate issue when the waste rock stockpile is very large. The CQA/CQC of liner placement for a large facility is the only means by which the integrity of the liner can be established initially. Maintaining liner integrity during waste rock placement on a large facility is the principal technical challenge, especially if the liner is a synthetic material. Even then, it is not, in my opinion, practicable to expect 100 percent achievement of the liner goal for a large waste rock stockpile facility. In my opinion, the question becomes how does a liner performance compare with the other leachate control methods (*e.g.*, headwall keyed to bedrock and interceptor wells). The liner is a physical boundary and, as such, must meet the physical boundary conditions to serve as a barrier to downward leachate migration. If the liner is some form of compacted earth material (*e.g.*, clay), then the effectiveness of the liner depends on the magnitude of the unsaturated hydraulic conductivity of the liner versus the percolation rate of water through the stockpile. If the percolation rate is greater than the unsaturated hydraulic conductivity of the liner, then a portion of the percolating water (*i.e.*, that part of percolation rate greater than the saturated vertical hydraulic conductivity of the liner) will be diverted by the liner and routed to where the liner system discharges. If the percolation rate is less than the unsaturated hydraulic conductivity of the liner, then the waste rock stockpile leachate will pass through the liner. Synthetic liners can achieve very low values of effective hydraulic conductivity, but suffer issues related to placement (*i.e.*, tears, seam integrity, *etc*.).

Ground water monitoring associated with waste rock stockpiles is addressed in 20.6.7.28 NMAC and specifics are discussed in sub-part (B). The requirements are essentially to monitor up gradient and down gradient of waste rock stockpiles (as well as all other copper mine facilities). This requirement is practical in that good data from up gradient locations provides the basis for defining background or baseline conditions in the ground water system. The other consideration with regard to background would be to establish, if possible, ground water conditions in the mineralized zone, especially in the shallow ground water where the fluctuating ground water table can generate sulfide oxidation conditions that reflect natural conditions. Placing ground water monitoring wells down gradient of waste rock stockpiles (as well as all other copper mine facilities) allows a comparison then between ground water conditions measured up gradient of the copper mine and ground water conditions down gradient of the copper mine. A difference in ground water quality that is above the natural background conditions of the mineralized zone, then, would be attributed to the waste rock stockpile. Placement of the down gradient monitoring wells is specified such that the wells are located as close down gradient as is practicable, acknowledging that the ground water monitoring wells cannot be inside the boundary where control systems (*e.g.*, headwalls keyed to bedrock) will be located.

The Proposed Rule sets forth the following construction requirements for new waste stockpiles and existing waste rock stockpiles in 20.6.7.21.C NMAC as follows:

> **C. Construction.**
> (1) **New waste rock stockpiles.** Construction of a new waste rock stockpile shall be performed in accordance with the applicable engineering requirements of Subsection B of 20.6.7.21 NMAC and 20.6.7.17 NMAC.
> (2) **Existing waste rock stockpiles.** A waste rock stockpile in existence on the effective date of the copper mine rule is not required to meet the design and construction requirements of Subsection B of 20.6.7.21 NMAC and may continue to operate as previously permitted under a discharge permit unless ground water monitoring of the stockpile pursuant to 20.6.7.28 NMAC requires implementation of corrective action under Subsection A of 20.6.7.30 NMAC.

The Proposed Rule specifies that waste rock stockpiles in existence prior to the effective date of the Proposed Rule is not bound to the design and construction requirements for new waste rock stockpiles as specified in the Proposed Rule. However, the waste rock stockpiles are still required to operate under a discharge permit or corrective action (as per Subsection A of 20.6.7.30 NMAC) if ground water impacts have occurred. The approach taken in the proposed Proposed Rule to address existing waste rock stockpiles is practical in that the existing requirements for copper mines is an effective means by which to ensure protection of the ground water resource. While the proposed Proposed Rule will provide greater assurance that a new waste rock stockpile has been designed to limit production of waste rock leachate that could impact ground water quality, requiring existing waste rock stockpiles to meet those same conditions would essentially require rebuilding of the waste rock stockpiles, which is not practicable nor justified with the existing types of controls in place.

The new requirements for waste rock stockpiles as specified in 20.6.7.21 NMAC represent an evolution in the state of knowledge in managing waste rock at copper mines. That is, the combined experiences and regulation of existing waste rock stockpiles has served as the basis for developing the language contained in 20.6.7.21 NMAC for designing and planning for waste rock stockpiles at copper mines. Thus, analysis and design of new waste rock stockpiles will benefit from the knowledge gained from existing waste rock stockpiles, while the existing waste rock stockpiles are effectively addressed with the existing regulatory requirements.

III. OPEN PITS (20.6.7.24 NMAC)

The Proposed Rule sets forth detailed requirements for open pits in 20.6.7.21 NMAC. "Open pit" and "open pit surface drainage area" are defined as follows:

> **20.6.7.7 DEFINITIONS:**
>
> A. Terms defined in the Water Quality Act and 20.6.2.7 NMAC shall have the meanings as given in such.
> B. A term defined in this part shall have the following meaning.
>
> . . . .
>
> (41) "Open pit" means the area within which ore and waste rock are exposed and removed by surface mining.
>
> (42) "Open pit surface drainage area" means the area in which storm water drains into an open pit and cannot feasibly be diverted by gravity outside the pit perimeter, and the underlying ground water is hydrologically contained by pumping or evaporation of water from the pit bottom.

Most copper mines are open pit mines in that current mining and beneficiation techniques make creation of an open pit a viable and effective method for mining copper ore. Defining and acknowledging the concept of an open pit as related to copper mining is critical to effective and realistic mine permitting and regulation. While an open pit can be identified as a separate facility of a copper mine, there are important implications of an open pit in the mine setting. An open pit will affect how storm water flows are managed, and, if the open pit intercepts the ground water system, will affect ground water flows in the vicinity of the open pit. Additionally, the open pit will remain a long-term part of the mine and will serve, both during mining and after mining, an important component of the overall mine water management system.

The definition of "open pit surface drainage area" provides specific acknowledgement that there will be a physical area surrounding an open pit where both surface drainage and ground water flow is to the open pit. Thus, water that contacts mine materials, such as a waste rock stockpile, or ground water that has been impacted by a mine facility that lies within the physical boundary defined by the open pit surface drainage area can and will be managed by the open pit and will not cause impact to surface or ground water outside the open pit surface drainage area. It is my professional opinion that both of these definitions are appropriate for the copper mining industry.

The Proposed Rule sets forth the following detailed requirements for open pits in 20.6.7.24 NMAC:

20.6.7.24. REQUIREMENTS FOR OPEN PITS

A. Operational requirements. A permittee operating an open pit shall operate the open pit pursuant to the following requirements, as applicable.

(1) The open pit shall remain within the area identified in the discharge permit.

(2) Stormwater shall be diverted outward and away from the perimeter of the open pit and, to the extent practicable, shall not be directed into the open pit.

(3) Water generated from within the perimeter of the open pit and pit dewatering activities shall be managed according to a mine operation water management plan. The water management plan shall be submitted to the department for approval in a discharge permit application for a new copper mine facility or in an application for a discharge permit renewal.

(4) During operation of an open pit, the standards of 20.6.2.3103 NMAC do not apply within the area of hydrologic containment.

The geologic evolution of a porphyry copper deposit is that natural geochemical weathering over geologic time results in a zone near the ground surface (10s to 100s of feet thick) where the original copper minerals have been chemically weathered to secondary oxide mineral forms (supergene enrichment). This is commonly referred to as the oxide zone of a copper deposit. There remains below the oxide zone remnants of the original copper deposit where the principal form of mineralization is the sulfide form regardless of the metal. This is referred to as the sulfide zone, which is typically located below the natural ground water table. Open pits that are developed in the oxide zone will often have different water chemistry, assuming the open pit contains water, than an open pit that penetrates into the sulfide zone. The oxide form of metal-bearing minerals are often more stable chemically (*i.e.*, less soluble) under oxidizing conditions than the sulfide form of metal-bearing minerals. If an open pit is developed into the sulfide zone and the pit walls containing sulfide minerals is allowed to weather chemically for long periods of time, then the pit water chemistry, assuming there is water in the pit, will likely be low pH, metal- and sulfate-bearing. A similar pit water chemistry may arise when the pit penetrates into the oxide zone, though concentrations could be lower. The geochemical and hydrologic conditions, in conjunction with local climate, mine plan, mine water management plan, and pit wall lithology greatly affects the final pit water chemistry. The presence of carbonate rocks can affect the overall pH of the pit water. In general, the higher the pH of water, the lower will be the equilibrium concentration of most metals. However, the overall effect of carbonate rocks on pit water chemistry depends on the relative abundance of carbonate rocks relative to the abundance of sulfide minerals and reactive oxide minerals. The bottom line is that each specific situation must be considered. It is important to note that many of the copper mines in New Mexico are located in areas with abundant carbonate rock, which is a good thing for open pit mining systems.

Mechanisms of discharge from an open pit depend completely on the physical setting/configuration of the open pit. If the open pit does not intercept the ground water system, then the mechanism for pit discharge is surface flow and vertical leakage. *See* Niccoli, 2009, which is attached as Exhibit Finley-6. If the open pit intercepts the ground water system, then the pit is in hydrologic contact with the ground water system and ground water flow will either flow into the pit, if the water level in the open pit is lower than the surrounding ground water system, or flow out of the pit, if the water level in the open pit is higher than the surrounding ground water system.

Open pit development occurs over time with concomitant changes in the possible methods by which water associated with the open pit could discharge. During the initial phases of open pit development, overburden rock is excavated and removed. In this time period, the principal mechanism of potential pit discharge is from storm water flows and could occur when the magnitude of the storm water flow exceeds the design standards of the storm water conveyance system. Further into the open pit development, when the oxide zone is exposed, the open pit could discharge water either during an extreme storm water flow event or by seepage from the bottom of the open pit. Such a discharge would require a break down in the open pit water management system in that water is generally not allowed to accumulate in an active open pit. Further still into the open pit development, the pit intercepts the sulfide zone; generally, penetration of the sulfide zone is coincident with interception of the ground water system. The primary mechanism of discharge could be from the pit bottom, but this could only occur with a breakdown in the open pit water management system in that no water is allowed to accumulate in an active open pit. Active water management in the open pit, via pumping, is necessary to continue open pit development. As the open pit is advanced into the sulfide zone, the distance between the bottom of the open pit and the surrounding ground water system increases such that the open pit becomes a low point in the surrounding ground water system. The resulting zone of influence imparted by the open pit on the surround ground water system is called the hydraulic capture zone. At this point in the open pit development, as long as the open pit remains dewatered, there will be no discharge from the open pit to the surrounding ground water system.

The previous description of the evolution of an open pit, and its effects on the hydrologic system, are the basis for development of a water management plan for the open pit. The focus of the open pit water management plan is to prevent build up of storm water within the foot print of the open pit (at any given stage of development), to prevent uncontrolled discharge accumulated water from the open pit, and to maintain hydraulic capture conditions of the open pit to prevent discharge to the ground water system. Because the essence of the open pit water management plan entails the removal of in-pit water, the open pit water management plan must necessarily be integrated into the overall mine water management plan to ensure that appropriate controls are in place to prevent overwhelming of the mine water management system that could result in an uncontrolled discharge to the environment.

An open pit water management plan specifies the method and controls that would be implemented during development and operation of the open pit. The methods and controls implemented are specified to prevent discharge of water from the open pit system. Maintaining a dry open pit is the most unequivocal means by which to demonstrate that no discharges to ground water have occurred.

The Proposed Rule does not distinguish between an open pit that acts as a terminal sink from an open pit that allows ground water flow through. When an open pit serves as a terminal sink, the water level in the pit is always lower than the water level in the surrounding ground water system. In contrast, an open pit that is flow through has a water level that is the same as, or elevated above, the surrounding ground water system.

An exemption of water in an operating open pit from WQCC standards is justified because all operating open pits will have active water management plans in place that prevent the accumulation of water in the open pit. The water removed from the open pit will be incorporated into the overall mine water management system and will be either consumed in the mining process or could be treated and discharged. Thus, there is, for all practical purposes, no risk to the environment by exempting water in an open pit during operations from WQCC standards.

In closure, an open pit that meets the criteria of a terminal sink is a viable option. The closure water management plan would have to either describe and justify how the open pit will passively remain a terminal sink or what controls will be put into place to ensure the terminal sink condition remains over time. In a terminal sink condition at closure, the pit discharges either by natural evaporation (*i.e.*, pit evaporation rate is equal to the pit inflow rate), in which case the discharge is pure water, or there is another control (such as low level pumping) that maintains the pit water level at an elevation to maintain terminal sink conditions. In the latter case, there may need to be some level of water treatment before discharge could occur.

IV. CONCLUSION

Based upon my professional training and experience, the proposed Copper Rule's regulations for Waste Rock Stockpiles (20.6.7.21 NMAC) and Open Pits (20.6.7.24 NMAC) are reasonable and appropriate regulations.

Jim Barton Finley, Jr.

EXHIBITS

1. Curriculum Vitae of Jim B. Finley, Jr.
2. Alpers, C.N. and D.K. Nordstrom. 1999. Geochemical modeling of water-rock interactions in mining environments. pp. 289-323. In G.S. Plumlee and M.J. Logsdon (eds.). The Environmental Geochemistry of Mineral Deposits. Part A: Processes, Techniques, and Health Issues. Vol. 6A. Society of Economic Geologists, Inc. Littleton, CO. (Exhibit Finley-2).
3. GARDGuide [need reference]
4. Morin, K.A. and N.M. Hutt. 1997. Environmental Chemistry of Minesite Drainage – Practical Theory and Case Studies. MDAG Publishing, Vancouver, British Columbia, Canada. P. 152. (Exhibit Finley – 4).
5. White, W.W. III, K.A. Lapakko, and R.L. Cox. 1999. Static test methods most commonly used to predict acid-mine drainage: Practical guidelines for use and interpretation. pp. 325-338. In G.S. Plumlee and M.J. Logsdon (eds.). The Environmental Geochemistry of Mineral Deposits. Part A: Processes, Techniques, and Health Issues. Vol. 6A. Society of Economic Geologists, Inc. Littleton, CO. (Exhibit Finely – 5).
6. Drever, J.I. 1997. *The Geochemistry of Natural Waters, 3rd Ed.* Prentice Hall, Engelwood Cliffs, N.J., 436 p. (Exhibit Finley – 6).
7. Niccoli, W.L. 2009. Hydrologic characteristics and classifications of pit lakes. In: Castendyk, D.N. and L.E. Eary (Eds.), Mine Pit Lakes: Characteristics, Predictive Modeling, and Sustainability. Society of Mining, Metallurgy, and Exploration, Littleton, CO, pp. 33-43. (Exhibit Finley – 7).