NOI EXHIBIT E: WRITTEN DIRECT TESTIMONY OF JOSEPH S. MEYER, PH.D.

TRIENNIAL REVIEW OF WATER QUALITY STANDARDS
NEW MEXICO WATER QUALITY CONTROL COMMISSION

EXPERT TESTIMONY OF JOSEPH S. MEYER, PH.D.

1. My name is Joseph S. Meyer. I live at 414 Anvil Way, Golden, Colorado 80401. Chino Mines Company has retained me as an expert on the toxicity of copper to fish and other aquatic organisms and on the derivation of site-specific aquatic life criteria for metals.
2. This testimony supports Chino's petition to the New Mexico Water Quality Control Commission (which I hereafter refer to as the "Commission"), to amend the regulations in Title 20, Chapter 6, Part 4 of the New Mexico Administrative Code (which I hereafter refer to as NMAC 20.6.4) The petition requests addition of site-specific aquatic life criteria for copper to NMAC 20.6.4 for certain surface waters located within the area known as the Chino Mines Smelter Tailings and Soil Investigation Unit (which I hereafter refer to as STSIU) near the towns of Bayard and Hurley in Grants County, New Mexico. See attached STSIU Surface Waters Map, attached hereto as Exhibit A.
3. In addition to using my professional experience and expertise when forming the opinions expressed below, I reviewed the cited documents.

PROFESSIONAL BACKGROUND AND QUALIFICATIONS

4. I am currently employed as a Technical Expert with ARCADIS U.S., Inc. I have worked on issues related to water quality for the past 38 years, including 17 years teaching and conducting research at the university level. That work has mainly focused on processes involved in the movement, interactions, and effects of chemicals, including copper, in aquatic systems. Based on my research and publications (see below), I am internationally known as an expert on the effects of metals to aquatic organisms, including fish and invertebrates.

5. I hold a Ph.D. in Zoology from the University of Wyoming (1986) and a B.S. in Chemical Engineering from Lehigh University (1973). I was a NATO Postdoctoral Research Fellow at the Swiss Federal Institute for Water Resources and Water Pollution Control

(EAWAG/ETH) from 1987 to 1988, followed by additional research at the same institute under Swiss funding from 1988 to 1989. From 1989 to 1990, I was a postdoctoral researcher with the University of Wyoming-National Park Service Research Center. During those years as an undergraduate and graduate student, I completed substantial coursework in biology, ecology, aquatic toxicology, chemistry, and the geochemistry of natural surface waters.

6. From 1990 through 1993, I was a Lecturer in the Fisheries Department at Humboldt State University (California), where I taught undergraduate-level courses in fish biology, freshwater fish ecology, limnology (the study of lakes, streams and wetlands), aquatic toxicology (the study of the effects of chemicals on aquatic organisms), and wastewater-treatment wetlands. I also supervised graduate students who investigated the fate of metals and nitrogen in the City of Arcata's wastewater treatment wetlands; and I oversaw state-mandated toxicity testing of the effluent from the City of Arcata's wastewater treatment system, which discharges into Humboldt Bay.

7. From 1994 through 2007, I was successively an Assistant Professor, Associate Professor, and Professor of Zoology at the University of Wyoming, where I taught undergraduate-level courses in general biology, general ecology, population biology, introduction to environment and natural resources, and risk analysis. Additionally, I taught graduate-level courses in aquatic toxicology, advanced limnology, and groundwater remediation. I also supervised graduate students who investigated the fate and effects of chemical pollutants in aquatic systems (e.g., boron, cadmium, copper, lead, nickel, selenium, silver, zinc; aromatic hydrocarbons in wastewaters from synthetic fossil fuel processes; and saline surface waters). While at the University of Wyoming, I was Director of the University's Red Buttes Environmental Biology Laboratory (1999-2004), which among other duties included responsibility for (a) conducting state-mandated toxicity testing and biomonitoring of the treated effluent discharged from the laboratory, (b) filing quarterly reports required for compliance with the laboratory's National Pollutant Discharge Elimination System (which I hereafter refer to as NPDES) permit, and (c) negotiating with the State of Wyoming for renewal of the NPDES permit for the laboratory.

8. Since 2007, I have been employed by ARCADIS U.S., Inc., where I consult on a wide variety of projects related to the processes involved in the movement, interactions, and effects of chemicals, including copper, in aquatic systems. Currently, I am the leader of the Surface Water Quality and Watershed Sciences group in ARCADIS's Environment Division.

9. I have lead-authored or co-authored 59 peer-reviewed articles in scientific journals, 1 peer-reviewed monograph, 12 book chapters, and 198 presentations at scientific meetings. I was lead editor of a peer-reviewed book titled "Toxicity of Dietborne Metals to Aquatic Organisms" (Meyer et al. 2005) and was lead author of a peer-reviewed book titled "Effects of Water Chemistry on Bioavailability and Toxicity of Waterborne Cadmium, Copper, Nickel, Lead, and Zinc to Freshwater Organisms" (Meyer et al. 2007). Additionally, I have participated in six SETAC-Pellston workshops on topics related to hazard assessment of effluents, bioavailability of chemicals, aquatic life criteria for metals, water quality criteria development, dietborne metal toxicity, and tissue-residue approaches to understanding the exposure to and effects of chemicals on aquatic organisms.

10. Thirty-two of the 59 peer-reviewed journal articles and both of the peer-reviewed books I lead-authored or lead-edited are related to the processes involved in the movement, interactions, or toxicity of copper in aquatic systems, with special emphasis on the way in which water chemistry parameters like pH, alkalinity, hardness, and dissolved organic carbon (DOC) concentration alter the toxicity of copper and other metals to aquatic organisms, including fish.

11. I was lead author or co-author of several of the peer-reviewed journal articles that led to the development of the Biotic Ligand Model (which I hereafter refer to as the BLM) as a regulatory tool for metals in aquatic systems (e.g., Meyer 1999, Meyer et al. 1999, Di Toro et al. 2001, Santore et al. 2001). The BLM explicitly accounts for the ways in which pH, alkalinity, hardness, and DOC modify the toxicity of metals like copper to fish and other aquatic organisms. In 2007, the U.S. Environmental Protection Agency (which I hereafter refer to as the USEPA) incorporated the BLM into its revision of the national freshwater

aquatic life criteria for copper, and I helped write the initial draft of that criteria document in 2003.

12. Therefore, I am well-qualified to discuss the importance of water chemistry on the bioavailability, or toxicity potential, of copper to fish and other aquatic organisms. I am also well-qualified to discuss the development and application of site-specific criteria that are scientifically valid and protective of aquatic life.

13. Of special bearing to Chino's petition to amend NMAC 20.6.4, I am co-author with Mr. Barry Fulton of the 2013 Revised Site-Specific Copper Toxicity Model Report for Smelter Tailings Soils IU Drainages – Chino Administrative Order on Consent, attached hereto as Exhibit B, and of a peer-reviewed paper titled "Development of a Regression Model to Predict Copper Toxicity to *Daphnia magna* and Site-Specific Copper Criteria across Multiple Surface-Water Drainages in an Arid Landscape", which was published in August 2014 in the scientific journal *Environmental Toxicology and Chemistry* (Fulton and Meyer 2014), attached hereto as Exhibit C. These documents reports the results of the study that forms the basis for the site-specific aquatic life criteria for copper that Chino has petitioned the Commission to adopt for certain waters in the Chino Mines STSIU.

14. My curriculum vitae is attached hereto as Exhibit D.

ASSESSMENT AND OPINIONS

15. I have been asked to offer scientific opinions about the site-specific aquatic life criteria for copper that have been proposed for certain waters in the Chino Mines STSIU. To derive the equation that is used to calculate those site-specific criteria, a series of copper toxicity tests was conducted in STSIU waters to provide data from which a statistical model to predict copper toxicity was developed. That statistical model is used to calculate the acute and chronic criteria for copper in STSIU waters, based on two important water chemistry parameters: alkalinity concentration and DOC concentration.

16. My opinion is that the proposed site-specific aquatic life criteria for copper are scientifically valid and will be protective of aquatic life in the specified waters in the Chino Mines STSIU. I base my opinions on the following reasons:

Reason #1: Water chemistry determines the bioavailability, or toxicity potential, of copper to aquatic organisms. Therefore, depending on water chemistries in distinct waters, the potential for copper to be toxic varies among waters that have different water chemistries. This is because the toxicity of copper decreases as concentrations of protective chemical parameters such as hardness, alkalinity, and DOC increase in the water.

Reason #2: Because the toxicity of copper differs when chemical composition differs among water bodies, it is scientifically valid to establish different aquatic life criteria for copper when the chemical compositions of receiving water bodies differ, particularly if such criteria remain protective of aquatic life. Stated simply, one size does not fit all, and default criteria thus can be overly-protective. For this reason, the USEPA and the NMAC allow for establishment of site-specific aquatic life criteria for different water bodies.

Reason #3: The current surface-water standards in the NMAC allow for adjustment of the aquatic life criteria for copper based on the hardness of the receiving water. However, water hardness is not the only water chemistry parameter that protects against copper toxicity.

Reason #4: Because the default aquatic life criteria for copper in New Mexico do not explicitly take into account all of the water chemistry parameters that can protect aquatic organisms against copper toxicity, more accurate criteria for copper can be developed by including other protective water chemistry parameters in the calculation of the criteria, namely alkalinity and DOC.

Reason #5: The site-specific aquatic life criteria for copper that have been proposed for certain waters in the Chino Mines STSIU are based on a scientifically-valid statistical regression equation. That statistical regression equation is scientifically valid because it was derived from results of copper toxicity tests that were conducted pursuant to the USEPA approved Water-Effect Ratio procedure in STSIU waters, which contain a wide range of water chemistries. These scientifically-valid copper toxicity tests were conducted using the USEPA Water-Effect Ratio procedure, which is a USEPA-approved method for establishing site-specific aquatic life criteria. The USEPA Water-Effect Ratio procedure is also an acceptable method for establishing site-specific aquatic life criteria in New Mexico (20.6.4.10.D.4 NMAC).

Reason #6: Because USEPA-specified methods were used to conduct the toxicity tests and calculate scientifically-valid adjustments to the hardness-based aquatic life criteria for copper in the Chino Mines STSIU waters, the proposed criteria provide the level of protection against copper toxicity that is intended by both the USEPA and, by reference, the NMAC. In fact, in STSIU water chemistries that contain low concentrations of protective chemical parameters, the proposed site-specific aquatic life criteria for copper are more stringent (i.e., even lower and thus more protective) than the corresponding hardness-based criteria.

Reason #7: The petition has been amended to state that the proposed site-specific copper criteria will not apply to water bodies that have been designated as habitat for the Chiricahua Leopard Frog. Therefore, potential concerns about whether the proposed site-specific criteria will protect this threatened species against copper toxicity are not relevant to consideration of the petition.

In the following paragraphs, I explain these reasons in more detail.

17. **Reason #1: Water chemistry determines the bioavailability, or toxicity potential, of copper to aquatic organisms. Therefore, depending on water chemistries in distinct**

waters, the potential for copper to be toxic varies among waters that have different water chemistries. This is because the toxicity of copper decreases as concentrations of protective chemical parameters such as hardness, alkalinity, and DOC increase in the water

18. It is well-established in scientific literature that the toxicity of copper to fish, invertebrates, and other aquatic organisms differs in waters that have different chemistries. For example, I summarized results of numerous studies that support that fact in a peer-reviewed book titled "*Effects of Water Chemistry on Bioavailability and Toxicity of Waterborne Cadmium, Copper, Nickel, Lead, and Zinc to Freshwater Organisms*" (Meyer et al. 2007).
19. Additionally, the USEPA's current aquatic life criteria document for copper (USEPA 2007) specifically states that chemical parameters such as pH, alkalinity, water hardness, and DOC can modify the toxicity of copper to aquatic organisms.
20. The pH of the water is a measure of its acidity (technically, it is a measure of the concentration of hydrogen ions in the water). The alkalinity of the water is a measure of its capacity to neutralize acidity (technically, it is a measure of the concentrations of the bicarbonate and carbonate ions in the water). The hardness is a measure of the concentrations of calcium and magnesium ions in the water. The DOC is a measure of the amount of natural organic chemicals that leach into the water from soil and organic matter (e.g., vegetation); and it is composed of, among other chemicals, humic and fulvic acids. Those acids are obvious as the tea-stained color in the water in ponds, bogs, ditches, ponds, etc., but they can be present in water at relevant concentrations even if the tea-stain color isn't visible.
21. The three water chemistry parameters that I emphasize in this testimony are hardness, alkalinity, and DOC concentration. They affect copper toxicity in two different ways.
22. In the first way that water chemistry parameters protect against copper toxicity, alkalinity ions and DOC can bind chemically with copper and thereby create chemical forms of copper that are less toxic to aquatic organisms because they are not available for the organism to uptake. This is an important distinction, because for a form of copper to be bioavailable (and thus be potentially toxic), it must be taken-up by an organism (Meyer et al. 2007). The copper bound to alkalinity ions and DOC is less toxic because the free, unbound copper ion (represented in chemical shorthand as Cu^{2+}) is the most available and most toxic form of

copper (USEPA 2007). As a consequence, as the alkalinity or DOC concentration increases in a given water, the toxicity of copper in that water decreases. Thereby, alkalinity concentration and DOC concentration protect against copper toxicity.

23. In the second way that water chemistry parameters protect against copper toxicity, the water hardness ions (represented in chemical shorthand as Ca^{2+} and Mg^{2+}) compete with copper ions for binding to aquatic organisms. If copper can't bind to an organism, it doesn't cause toxicity. As a consequence, as the hardness increases in a given water, less copper binds to the organisms; and thus, the toxicity of copper in that water decreases. Thereby, water hardness protects against copper toxicity.
24. Therefore, water chemistry determines the toxicity and availability of copper to aquatic organisms. When a range of water bodies that contain a range of chemical composition is considered, no one concentration of copper can be designated as the threshold for toxicity in all those water bodies. Instead, the threshold for copper toxicity will vary among those water bodies. This is the situation in the waters in the Chino Mines STSIU.
25. **Reason #2: Because the toxicity of copper differs when chemical composition differs among water bodies, it is scientifically valid to establish different aquatic life criteria for copper when the chemical compositions of receiving water bodies differ, particularly if such criteria remain protective of aquatic life. Stated simply, one size does not fit all, and default criteria thus can be overly-protective. For this reason, the USEPA and the NMAC allow for establishment of site-specific aquatic life criteria for different water bodies.**
26. The USEPA's current aquatic life criteria document and calculation procedure for copper in fresh water (USEPA 2007) allow for a sliding scale of national criteria for copper, depending on the chemical composition of the water body. The criteria are calculated by a computer program (the BLM), which uses site-specific input data about the chemical composition of a given water, including the hardness, alkalinity, and DOC concentration. As the hardness, alkalinity, or DOC concentration increases, the USEPA's national criteria concentration for copper increases.
27. The USEPA also allows site-specific aquatic life criteria for copper to be calculated using a water-effects ratio (which I hereafter refer to as WER) procedure. Briefly, in the WER procedure, the toxicity of copper is tested side-by-side in laboratory water and in water

collected from the site of interest. The laboratory water used in the WER procedure represents the types of water in which New Mexico's default aquatic life criteria for copper (i.e., the current acute and chronic aquatic life criteria for copper in 20.6.4.900.I NMAC, which are based only on the hardness concentration of the water) were derived in 1995 by the U.S. Environmental Protection Agency. If copper is less toxic in a water sample collected from the site of interest than it is in the laboratory water, the New Mexico criteria for copper are overly conservative (i.e., lower than necessary) and thus can validly be increased; and vice versa. The scientific basis for the WER method is described in the USEPA (1994) WER guidance document. As described in that document, when conducting a WER test, "if there is a difference in toxicity and it is not taken into account, the aquatic life criterion for the body of water will be more or less protective than intended by EPA's Guidelines for Deriving Numerical Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" (see first paragraph on page xi in USEPA 1994).

28. In New Mexico, 20.6.4.10.D.4 NMAC allows for site-specific aquatic life criteria for copper. That section of the administrative code specifies several ways by which site-specific criteria can be derived, including three that I mention in this testimony: (a) the USEPA (1994) WER procedure for metals; (b) the USEPA (2001) streamlined WER procedure for discharges of copper; and (c) the USEPA (2007) BLM. As described in the USEPA WER Guidance, "A site-specific criterion is intended to come closer to providing the intended level of protection to the aquatic life at the site, usually by taking into account the biological and/or chemical conditions (i.e., the species composition and/or water quality characteristics)" (see last paragraph on page 1 in USEPA 1994).
29. Both the BLM and the WER are scientifically valid procedures to derive site-specific criteria for copper.
30. The BLM <u>explicitly</u> accounts for the ways in which the chemical composition of a given water modifies copper toxicity. That is, the effect of each water chemistry parameter on copper toxicity can be determined by varying the value inputted into the BLM computer program and then evaluating the resulting change in toxicity. The BLM can also be used to calculate how the copper criteria would change when the chemistry of the water changes. The scientific basis for the BLM has been well-established in numerous peer-reviewed articles that have been published in scientific journals for more than a decade. For example,

two of the early publications (one of which I co-authored) that established the scientific legitimacy of the BLM are Di Toro et al. (2001) and Paquin et al. (2003). Additional publications demonstrating the scientific validity of BLM-type models are summarized in the peer-reviewed book about metal toxicity on which I was the lead author (Meyer et al. 2007).

31. The BLM provides a mechanistic underpinning for the equation that has been proposed for calculation of the site-specific aquatic life criteria for copper in the specified Chino Mines STSIU waters. However, that proposed equation was derived from results of WER toxicity tests conducted in STSIU waters, thus making it more specific to the chemical compositions of the STSIU waters than is the more general copper BLM.
32. In contrast to the BLM, the WER procedure <u>implicitly</u> accounts for the ways in which the chemical composition of a given water modifies copper toxicity. That is, the WER procedure does not explicitly identify which chemical(s) in the water are protecting against copper toxicity; instead, it only indicates whether a protective effect is or is not present. Instead, in accordance with the USEPA WER guidance (USEPA 1994, 2011), only the results of the WER testing are needed to derive the equation that has been proposed for calculation of site-specific aquatic life criteria for copper in the specified Chino Mines STSIU waters.
33. **Reason #3: The current surface-water standards in the NMAC allow for adjustment of the aquatic life criteria for copper based on the hardness of the receiving water. However, water hardness is not the only water chemistry parameter that protects against copper toxicity.**
34. The current acute and chronic aquatic life criteria for copper in 20.6.4.900.I NMAC are, in fact, site-specific criteria, because the criteria concentrations differ in waters containing different hardness. However, those hardness-based aquatic life criteria are not generally referred to as site-specific criteria. Instead, they are default criteria that are applicable statewide (but still dependent on the hardness of the given water instead of being a single number for all surface waters in New Mexico). In general usage, the term “site-specific” is reserved for criteria that are derived using the other procedures listed in 20.6.4.10.D.4 NMAC, such as the WER and BLM procedures.
35. Although the default aquatic life criteria in New Mexico are derived using only the hardness of the water in question, other chemicals in natural waters can also protect against copper toxicity. In fact, in the WER tests for surface waters in the Chino Mines STSIU, copper

toxicity was not well-correlated with hardness (i.e., hardness was a poor predictor of copper toxicity). Instead, the toxicity of copper varied by 12-fold within a narrow range of water hardness (see Section 3.2.1 in ARCADIS 2013, and page 1869 in Fulton and Meyer 2014). Alkalinity concentration and DOC concentration were much better predictors of copper toxicity in the STSIU waters. Specifically, water hardness only predicts 10 percent of the variation in copper toxicity among the various STSIU waters that were tested, whereas the combination of alkalinity concentration and DOC concentration used in the proposed WER equation predicts 85 percent of the variation in copper toxicity among the various STSIU waters that were tested (see Sections 3.2.1 and 3.2.4 in ARCADIS 2013, and Tables 2 and 3 in Fulton and Meyer 2014). In my experience, 85 percent predictability by any model is quite high for aquatic toxicity tests conducted in natural waters collected from the field, and it is even high predictability for aquatic toxicity tests conducted in laboratory waters.

36. **Reason #4: Because the default aquatic life criteria for copper in New Mexico do not explicitly take into account all of the water chemistry parameters that can protect aquatic organisms against copper toxicity, more accurate criteria for copper can be developed by including other protective water chemistry parameters in the calculation of the criteria, namely alkalinity and DOC.**

37. As stated in #26-#28 above, the USEPA has explicitly acknowledged this in two major ways by allowing for establishment of aquatic life criteria for copper based on other water chemistry parameters over the years. In turn, the NMAC explicitly allows development of site-specific criteria for copper based on USEPA guidance that differ from the default hardness-based criteria.

38. The New Mexico- and USEPA-approved procedures for deriving WER-based site-specific aquatic life criteria were followed in development of the equation that has been proposed for calculation of site-specific aquatic life criteria for copper in the specified Chino Mines STSIU waters.

39. **Reason #5: The site-specific aquatic life criteria for copper that have been proposed for certain waters in the Chino Mines STSIU are based on a scientifically-valid statistical regression equation. That statistical regression equation is scientifically valid because it was derived from results of copper toxicity tests that were conducted pursuant to the**

USEPA approved Water-Effect Ratio procedure in STSIU waters, which contain a wide range of water chemistries. These scientifically-valid copper toxicity tests were conducted using the USEPA Water-Effect Ratio procedure, which is a USEPA-approved method for establishing site-specific aquatic life criteria. The USEPA Water-Effect Ratio procedure is also an acceptable method for establishing site-specific aquatic life criteria in New Mexico (20.6.4.10.D.4 NMAC).

40. The basis for the proposed site-specific aquatic life criteria for copper is a series of WER toxicity tests conducted with copper added to laboratory water and to waters collected from various drainages in the Chino Mines STSIU during different times of the year. This range of water samples collected across locations in the STSIU and across time was intended to capture the range of chemical conditions that might modify the toxicity of copper to aquatic organisms.
41. Water chemistry varies across the Chino Mines STSIU because of localized differences in soils, geology (i.e., rock types), geomorphology (i.e., physical forms of geologic features, such as hills, valleys, slopes), hydrology (i.e., magnitude, frequency, and duration of water flow), and surrounding upland landscapes (i.e., types and amounts of vegetation) (see page 1866 in Fulton and Meyer 2014). In general, the water chemistry changes along the elevation gradients from the higher, mountainous portions of the STSIU down to the lower, valley-and-basin portions of the STSIU.
42. All of the WER toxicity tests were conducted according to USEPA (1994, 2001) guidance, as specified in 20.6.4.10.D.4 NMAC. This included using a standard aquatic toxicity-testing organism (the invertebrate *Daphnia magna*) that is recommended by USEPA (1994, 2001) for this type of WER test.
43. From the results of those WER toxicity tests, WER values were calculated for each water sample. A WER is the ratio of the concentration of copper that causes 50% mortality in the site water divided by the concentration of copper that causes 50% mortality in laboratory water containing the same or very similar hardness as the site water.
44. Therefore, the WER is the factor by which the default hardness-based aquatic life criteria for copper can be multiplied to derive site-specific criteria for a given water.
45. Typically, a WER is applied to one water body, usually downstream of a point source discharge of one or more chemicals. However, the Chino Mines STSIU covers approximately

60 square kilometers (i.e., approximately 23 square miles) and contains more than 100 miles of stream bed in 12 different drainages, the majority of which, are dry sandy arroyos/washes. Point-source discharges of copper do not occur in the STSIU surface waters. Instead, diffuse copper is present from historical emissions from mining smelting and from natural mineralized soil in some portions of the Chino Mines STSIU. Consequently, an approach was needed that would allow calculation of aquatic life criteria for copper not only in the STSIU waters that were tested during the WER-toxicity study, but also for any other STSIU water for which adequate water chemistry was available or could become available in the future.

46. To address that need, ARCADIS (2013; see Section 3.2.4) and Fulton and Meyer (2014; see pages 1869-1870) used the WER values calculated from the results of the WER-toxicity tests to derive an equation to predict the concentration of copper that would cause 50% mortality in any surface-water chemistry that might be found in the Chino Mines STSIU waters. Hereafter I refer to that concentration as the EC50 value for copper.
47. The resulting equation for predicting the copper EC50 values in STSIU waters is the result of a statistical regression of the EC50 values measured in the WER toxicity tests compared to the concentrations of various chemical parameters in the waters collected from the Chino Mines STSIU. That equation was derived using a well-accepted, scientifically-valid statistical regression method that is described in detail in ARCADIS (2013; see Sections 2.2 and 3.2.4) and Fulton and Meyer (2014; see pages 1867 and 1869-1870).
48. The combination of water chemistry parameters that best predicted the measured EC50s in the tested waters was chosen to predict the toxicity of copper in all STSIU waters. That choice is scientifically valid, because the ranges of water chemistry parameters in the tested STSIU waters are representative of water chemistries known to occur in the STSIU drainages. Water chemistry determines the toxicity of copper to aquatic organisms, as discussed in #18-#24 above. Therefore, because the predictive model was calibrated across the wide ranges of water chemistry parameters that occur in the STSIU, it is applicable to all waters in the STSIU.
49. The best predictor of copper toxicity in the Chino Mines STSIU waters was a combination of alkalinity concentration and DOC concentration. The resulting regression equation is:

$$\text{EC50 of copper} = 10^{0.588 + (0.703 \times \log \text{DOC}) + (0.395 \times \log \text{Alkalinity})}$$

where the EC50 is expressed in units of micrograms of copper per liter (g Cu/L), the DOC concentration is expressed in units of milligrams of carbon per liter (mg C/L), and alkalinity is expressed in units of milligrams per liter (mg/L) as calcium carbonate. All of these units are standard ways of expressing the concentrations of metals, DOC, and alkalinity in water. This combination of alkalinity concentration and DOC concentration accounts for 85 percent of the variation in the toxicity of copper to *Daphnia magna* in the tested STSIU waters. Stated alternatively, 85 percent of the differences in toxicity of copper in the STSIU waters were accounted for by the different combinations of alkalinity concentration and DOC concentration in those waters. This is excellent predictability, given the wide variety of factors that can affect the toxicity of metals in natural waters (e.g., see Sprague 1985 for a discussion of variability of toxicity of chemicals to aquatic organisms). For comparison, only 10 percent of the differences in toxicity of copper in the STSIU waters were accounted for by water hardness, which is the parameter used to calculate the default aquatic life criteria for copper in New Mexico.

50. The equation shown in #49 above is part of the numerator of the proposed equation for calculating the WER in the specified waters in the STSIU, as shown on page 2 of the petition that requests site-specific aquatic life criteria for copper in certain Chino Mines STSIU waters (Chino 2014). The remaining terms in the numerator of the WER equation in the petition simply normalize the predicted copper toxicity to a common water hardness of 100 mg/L as calcium carbonate, for comparison to the EC50 value that would be predicted based only on the hardness of the STSIU water (i.e., the 19.31 in the denominator of the proposed WER equation). This hardness-normalization step is based on USEPA WER guidance (i.e., USEPA 1994, 2001). The “19.31” term in the denominator of the proposed WER equation comes from the USEPA WER guidance (USEPA 2001), and represents the average EC50 value for the tested species (*D. magna*) at a hardness of 100 mg/L based on 55 acceptable toxicity test results.
51. To calculate the proposed site-specific acute and chronic aquatic life criteria for any specified water in the Chino Mines STSIU, the WER value, calculated using the proposed WER

equation, is multiplied by the default acute or chronic hardness-based criterion (as determined using the hardness-based equations for copper in 20.6.4.900.I NMAC).

52. The use of a statistical-regression equation to calculate site-specific criteria for copper is exactly analogous to the way in which a statistical-regression equation is used to calculate the current hardness-based criteria for copper, except hardness is replaced by alkalinity concentration and DOC concentration as the determinants of the proposed site-specific criteria. Use of the proposed regression equation to calculate site-specific criteria for copper is also exactly analogous to the way in which a statistical regression equation is used to calculate the current chronic aquatic life criteria for ammonia, except temperature and pH are replaced by alkalinity concentration and DOC concentration as the determinants of the proposed site-specific criteria.
53. As stated by USEPA (1994, 2001), this WER procedure for deriving site-specific aquatic life criteria provides a scientifically-valid way to account for the toxicity-modifying effects of non-hardness chemicals (e.g., alkalinity and DOC) in any water, beyond the toxicity-modifying effects of water hardness that are already accounted for in the current hardness-based aquatic life criteria specified in 20.6.4.900.I NMAC.
54. As stated by USEPA (1994, 2001), a WER derived using the USEPA-prescribed procedures is valid for use in site-specific adjustment of both acute and chronic aquatic life criteria for copper.
55. And because the USEPA-approved procedures are scientifically valid and were used to conduct the WER-toxicity tests and to derive the WER values on which the proposed statistical-regression equation is based, the method to derive site-specific aquatic life criteria for copper that has been proposed for use with certain waters in the Chino Mines STSIU is scientifically valid.
56. Moreover, the USEPA-approved BLM for copper (USEPA 2007) provides a scientific underpinning for the alkalinity- and DOC-based statistical-regression equation that has been proposed for deriving site-specific aquatic life criteria for copper in certain STSIU waters. However, for the STSIU waters, the WER-based site-specific adjustments to the default hardness-based criteria are more reliable than the USEPA-recommended, BLM-based site-specific national criteria for copper, because the WER-based site-specific criteria are a result of WER-toxicity tests conducted in actual STSIU waters. Therefore, potential differences are

accounted for in, for example, the type of DOC in the STSIU waters compared to the more general type of DOC from wetter climates that was used to calibrate the USEPA-approved BLM for copper.

57. It is especially important to recognize that water hardness was not identified as a statistically significant predictor of copper toxicity to aquatic life in the Chino Mines STSIU waters, even though the default aquatic life criteria for copper in 20.6.4.900.I NMAC are based only on water hardness. This is not uncommon in natural waters, because alkalinity and/or DOC provide much stronger protection against copper toxicity than does water hardness. This is discussed in more detail in ARCADIS (2013; see Section 3.2.1) and Fulton and Meyer (2014; see pages 1869-1870), with reference to other studies in peer-reviewed scientific journals that reach similar conclusions. Therefore, the alkalinity- and DOC-based statistical-regression equation that has been proposed for deriving site-specific aquatic life criteria for copper in certain STSIU waters is supported by results of independent scientific studies. However, the actual equation derived for STSIU waters should not be applied to non-STSIU waters without confirmatory tests in those non-STSIU waters.

58. It is also important to recognize that pH was not identified as a statistically significant predictor of copper toxicity to aquatic life in the Chino Mines STSIU waters, even though pH is a chemical input for BLM predictions of copper toxicity and has been identified as a significant predictor of copper toxicity in some other waters (e.g., see the discussion on page 1870 in Fulton and Meyer 2014). More details about the results of the statistical analysis that led to this conclusion are provided in ARCADIS (2013; see Section 3.2.3) and Fulton and Meyer (2014; see pages 1869-1870).

59. Reason #6: Because USEPA-specified methods were used to conduct the toxicity tests and calculate scientifically-valid adjustments to the hardness-based aquatic life criteria for copper in the Chino Mines STSIU waters, the proposed criteria provide the level of protection against copper toxicity that is intended by both the USEPA and, by reference, the NMAC. In fact, in STSIU water chemistries that contain low concentrations of protective chemical parameters, the proposed site-specific aquatic life criteria for copper are more stringent (i.e., even lower and thus more protective) than the corresponding hardness-based criteria.

60. By definition, the USEPA's national aquatic life criteria for all chemical pollutants are intended to protect at least 95 percent of the species in a water body (Stephan et al. 1985). And because the default New Mexico aquatic life criteria for copper originate from a previous version of USEPA's national aquatic life criteria for copper (USEPA 1995), the aquatic life criteria for copper in 20.6.4.900.I NMAC are intended to protect at least 95% of the species in a water body.
61. In their guidance for deriving WER-based site-specific aquatic life criteria, USEPA (1994) specifically stated that when USEPA-recommended methods are used to conduct WER studies and then calculate the associated WER values, the resulting WER-based site-specific criteria for chemical pollutants will provide the same intended level of protection as the default national criteria. By reference through inclusion in 20.6.4.10.D.4 NMAC of the USEPA-recommended methods for deriving site-specific aquatic life criteria using the WER procedure (USEPA 1994, 2001), New Mexico also intends that WER-based site-specific criteria will provide the same intended level of protection as the default hardness-based criteria.
62. In fact, the proposed site-specific aquatic life criteria for copper can be even more stringent (i.e., lower and thus more protective) than the corresponding hardness-based criteria when applied to surface waters containing low DOC and/or alkalinity concentrations. As described in the petition, the proposed equation does not recommend a lower limit for DOC or alkalinity concentrations for an STSIU surface-water sample, thus allowing for low copper criteria when applicable. The following two examples illustrate this point.
    a. When the proposed WER equation is applied to a hardness concentration of 100 mg/L, an alkalinity concentration of 75 mg/L, and a DOC concentration of 0.5 mg/L, a WER value of 0.678 is calculated, which results in a site-specific acute criterion for dissolved copper of 9.1 micrograms per liter (µg/L). For comparison, the default hardness-based acute criterion for dissolved copper at 100 mg/L hardness is 13.3 µg/L.
    b. When the proposed WER equation is applied to a hardness concentration of 100 mg/L, an alkalinity concentration of 25 mg/L, and a DOC concentration of 1 mg/L, a WER value of 0.678 is calculated, which results in a site-specific acute criterion for dissolved copper of 9.6 µg/L, which again is lower (i.e., more restrictive) than the default 13.3 µg/L hardness-based acute criterion for dissolved copper at 100 mg/L hardness.

63. **Reason #7: The petition has been amended to state that the proposed site-specific copper criteria will not apply to water bodies that have been designated as habitat for the Chiricahua Leopard Frog. Therefore, potential concerns about whether the proposed site-specific criteria will protect this threatened species against copper toxicity are not relevant to consideration of the petition.**
64. The Chiricahua Leopard Frog currently is listed as a threatened species by the U.S. Fish and Wildlife Service, and some waters (Ash and Bolton Springs) in the Chino Mines STSIU are designated habitat for that species. No other aquatic species in the STSIU is listed as threatened, endangered, or otherwise of special concern.
65. ARCADIS (2013; see Appendix 5) applied the proposed regression equation to measured water chemistries reported in the only known study of copper toxicity to the Chiricahua Leopard Frog (Little and Calfee, 2008), and demonstrated that the resulting site-specific aquatic life criteria for copper would be protective of the most sensitive endpoint reported in that study. However, to provide a more-streamlined process and to minimize the amount of interagency interactions that would be required to fully address potential concerns about threatened-and-endangered species, this petition is not proposing to apply the site-specific copper criteria to the designated Chiricahua Leopard Frog habitat.

SUMMARY

66. **20.6.4.10.D.4 NMAC allows for the derivation of site-specific aquatic life criteria for copper.**
67. **The proposed site-specific aquatic life criteria for copper are scientifically valid and will provide the intended level of protection to aquatic life in the specified waters in the Chino Mines STSIU.**
68. **The proposed site-specific criteria for copper have been derived from results of scientifically-valid WER toxicity tests that were conducted according to USEPA (1994, 2001) guidance, which by reference are also approved in 20.6.4.10.D.4 NMAC. As suggested by the Surface Water Quality Branch of the New Mexico Environment Department, the methods and results of that study were published in a peer-reviewed article in scientific journal (Fulton and Meyer 2014), thus further supporting the**

scientific validity and acceptability of the WER tests and the proposed regression-based site-specific copper criteria.

69. **The statistical-regression-based equation that has been proposed for the calculation of site-specific criteria for copper in the specified waters in the Chino Mines STSIU was derived using a scientifically-valid statistical analysis.**
70. **The proposed WER-based site-specific criteria for copper have a scientifically-valid unperpinning in a vast body of peer-reviewed scientific publications that demonstrate the protectiveness of some water chemistry parameters (e.g., hardness, alkalinity, and DOC concentration) against copper toxicity to aquatic organisms (e.g., see a review of that literature in Meyer et al. 2007).**
71. **The USEPA's recently-adopted revision to the national aquatic life criteria for copper (USEPA 2007), which is based on the copper BLM, also provides a mechanistic underpinning for the proposed WER-based site-specific criteria for copper, because the copper BLM explicitly incorporates toxicity-modifying water chemistry parameters such as hardness, alkalinity, and DOC concentration into its predictions of copper toxicity and into its calculations of aquatic life criteria for copper. In both the BLM-based and the proposed WER-based calculations, copper toxicity decreases and thus the aquatic life criteria increase as hardness, alkalinity, and DOC concentration increase.**
72. **Despite differing from the default hardness-based aquatic life criteria for copper in 20.6.4.900.I NMAC, the proposed site-specific aquatic life criteria for copper will provide the intended level of protection to aquatic life in the specified waters in the Chino Mines STSIU.**
73. **The petition for site-specific aquatic life criteria for copper in certain waters in the Chino Mines STSIU specifically excludes Chiricahua Leopard Frog habitat from the list of waters to which the site-specific criteria will apply; and no other threatened, endangered, or other species of special concern occur in the STSIU waters.**
74. **Therefore, the Commission will not violate any USEPA regulatory constraints and it will not contradict the current NMAC by adopting the site-specific aquatic life criteria for copper that have been proposed by Chino (2014) for certain waters in the Chino Mines STSIU. Moreover, exclusion of designated habitat for the Chiricahua Leopard**

Frog from the list of waters to which the proposed site-specific criteria apply will obviate potential regulatory concerns about effects on that federally-listed threatened species.

Literature Cited

ARCADIS. 2013. Revised Site-Specific Copper Toxicity Model Report: Chino Mine, Vanadium, New Mexico. October, 2013.

Chino. 2014. Freeport-McMoRan Chino Mines Company's Petition to Amend the Surface Water Quality Standards (20.6.4 NMAC) and Request for Hearing. Submitted to the New Mexico Water Quality Control Commission.

Di Toro, D.M., H.E. Allen, H.L. Bergman, J.S. Meyer, P.R. Paquin and R.C. Santore. 2001. Biotic ligand model of the acute toxicity of metals. 1. Technical basis. *Environmental Toxicology and Chemistry* 20:2383-2396.

Fulton, B.A. and J.S. Meyer. 2014. Development of a regression model to predict copper toxicity to *Daphnia magna* and site-specific copper criteria across multiple surface-water drainages in an arid landscape. *Environmental Toxicology and Chemistry* 33:1865-1873.

Little, E.E, and R.D. Calfee. 2008. Toxicity of Herbicides, Piscicides, and Metals to the Threatened Chiricahua Leopard Frog (*Rana chiricahuensis*), Administrative report prepared for the U.S. Fish and Wildlife Service by the U.S. Geological Survey, Columbia Environmental Research Center, Columbia, MO.

Meyer, J.S. 1999. A mechanistic explanation for the ln(LC50) vs. ln(hardness) adjustment equation for metals. *Environmental Science and Technology* 33:908 912.

Meyer, J.S., R.C. Santore, J.P. Bobbitt, L.D. DeBrey, C.J. Boese, P.R. Paquin, H.E. Allen, H.L. Bergman and D.M. Di Toro. 1999. Binding of nickel and copper to fish gills predicts toxicity when water hardness varies, but free ion activity does not. *Environmental Science and Technology* 33:913 916.

Meyer, J.S., W.J. Adams, K.V. Brix, S.N. Luoma, D.R. Mount, W.A. Stubblefield and C.M. Wood (eds.). 2005. *Toxicity of Dietborne Metals to Aquatic Organisms*. SETAC Press, Pensacola, Florida, USA.

Meyer, J.S., S.J. Clearwater, T.A. Doser, M.J. Rogaczewski and J.A. Hansen. 2007. *Effects of Water Chemistry on the Bioavailability and Toxicity of Waterborne Cadmium, Copper, Nickel, Lead, and Zinc to Freshwater Organisms.* SETAC Press, Pensacola, Florida, USA.

Paquin, P.R., J.W. Gorsuch, S. Apte, G.E. Batley, K.C. Bowles, P.G.C. Campbell, C.G. Delos, D.M. Di Toro, R.L. Dwyer, F. Galvez, R.W. Gensemer, G.G. Goss, C. Hogstrand, C.R. Janssen, J.C. McGeer, R.B. Naddy, R.C. Playle, R.C. Santore, U. Schneider, W.A. Stubblefield, C.M. Wood and K.B. Wu. 2002.The biotic ligand model: A historical overview. *Comparative Biochemistry and Physiology Part C Toxicology and Pharmacology* 133:3-35.

Santore, R.C., D.M. Di Toro, P.R. Paquin, H.E. Allen and J.S. Meyer. 2001. Biotic ligand model of the acute toxicity of metals. 2. Application to acute copper toxicity in freshwater fish and *Daphnia*. *Environmental Toxicology and Chemistry* 20:2397-2402.

Sprague, J.B. 1985. Factors that modify toxicity. pp. 124-163 in: G.M. Rand and S.R. Petrocelli (eds.), *Fundamentals of Aquatic Toxicology: Methods and Applications*, Hemisphere Publishing Corporation, New York, NY.

Stephan, C.E., D.I. Mount, D.J. Hansen, J.H. Gentile, G.A. Chapman and W.A. Brungs. 1985. Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses. U.S. Environmental Protection Agency, Duluth, MN, Narragansett, RI, and Corvallis, OR.

USEPA (U.S. Environmental Protection Agency). 1994. Interim Guidance on Determination and Use of Water-Effect Ratios for Metals. EPA-B-94-001. U.S. Environmental Protection Agency, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1995. 1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water. EPA-820-B-96-001. U.S. Environmental Protection Agency, Washington, DC.

USEPA. 2001. Streamlined Water-Effect Ratio Procedure for Discharges of Copper. EPA-822-R-01-005. U.S. Environmental Protection Agency, Washington, D.C.

USEPA (U.S. Environmental Protection Agency). 2007. Aquatic Life Ambient Freshwater Quality Criteria – Copper: 2007 Revision. EPA-822-R-07-001. U.S. Environmental Protection Agency, Washington, DC.