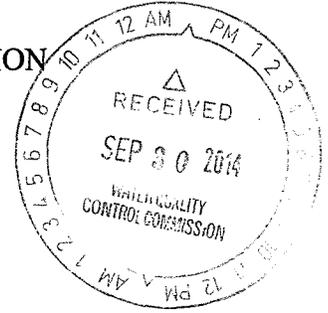


COPY

STATE OF NEW MEXICO
BEFORE THE WATER QUALITY CONTROL COMMISSION



_____)
)
In the Matter of:)
)
PROPOSED AMENDMENTS TO)
STANDARDS FOR INTERSTATE)
AND INTRASTATE SURFACE)
WATERS, 20.6.4 NMAC)
_____)

No. WQCC 14-05(R)

**FREEPORT-McMoRan CHINO MINES COMPANY'S PETITION TO AMEND THE
SURFACE WATER QUALITY STANDARDS (20.6.4 NMAC) AND
REQUEST FOR HEARING**

INTRODUCTION

Freeport-McMoRan Chino Mines Company ("Chino") hereby petitions the Water Quality Control Commission ("Commission") to amend the Commission's regulations in Title 20, Chapter 6, Part 4 of the New Mexico Administrative Code ("NMAC") titled "*Standards for Interstate and Intrastate Surface Waters*" ("Rules"). This petition is filed in accordance with the Scheduling Order for this matter dated July 10, 2014 and the Procedural Order of the same date.

The proposed amendment would add site-specific criteria for copper for certain surface waters located within the Mimbres River Closed Basin (hydrologic unit code HUC8-13030202) near the towns of Bayard and Hurley, New Mexico and also located within an area known as the Chino Mines Site Smelter Tailings Soil Investigation Unit (STSIU waters).

PROPOSED AMENDMENT

Add a new Section, 20.6.4.902 NMAC stating as follows:

20.6.4.902 SITE-SPECIFIC STANDARDS

A. A site-specific adjustment to copper criteria for the applicable aquatic life designated use for a segment of Lampbright Draw and certain of its tributaries and certain

tributaries of Whitewater Creek located in the Mimbres River Closed Basin shall be applied as described in this subsection.

(1) the criteria adjustment for copper described in paragraph (2) of this subsection shall apply only to the portions of the surface waters located within an area known as the Chino Mines Site Smelter Tailings Soil Investigation Unit (“STSIU”) and described as follows:

(a) the mainstem of Lampbright Draw beginning at the confluence of Lampbright Draw with Rustler Canyon to the intersection of Lampbright Draw with the southern STSIU boundary and all tributaries thereof that originate west of Lampbright Draw, including Rustler Canyon and Martin Canyon;

(b) Lucky Bill Canyon and all tributaries thereof;

(c) Chino Mines property Subwatershed Drainages A, B, C, D-1, D-2, D-3 and all tributaries thereof; and

(d) Chino Mines property Subwatershed Drainages E-1, E-2, and E-3.

(2) For the waters listed in paragraph (1) of this subsection, the aquatic life criteria for copper as set forth in Subsection I of 20.6.4.900 NMAC shall be adjusted by multiplying the applicable acute or chronic aquatic life criterion set forth in Subsection I of this section by the Water Effect Ratio (“WER”) adjustment expressed by the following equation:

$$WER = \frac{[10^{0.588+(0.703 \times \log DOC)+(0.395 \times \log Alkalinity)}] \times \left(\frac{100}{Hardness}\right)^{0.9422}}{19.31}$$

For purposes of this paragraph, alkalinity is expressed in units of mg/L as CaCO₃. In waters that contain alkalinity concentrations greater than 250 mg/L, a value of 250 mg/L shall be used in the equation. No lower bound (or limit) for alkalinity concentrations shall be used in the equation. DOC is dissolved organic carbon, expressed in units of mg C/L. In waters that contain DOC concentrations greater than 16 mg C/L, a value of 16 mg C/L shall be used in the equation. No lower bound (or limit) for DOC concentrations shall be used in the equation. Hardness is expressed in units of mg/L as CaCO₃. In waters that contain hardness concentrations greater than 400 mg/L, a value of 400 mg/L shall be used in the equation. No lower bound (or limit) for hardness concentrations shall be used in the equation. The alkalinity, hardness and DOC concentrations used to calculate the WER value are those measured in the subject water sample. The term “19.31” is a *Daphnia magna* Species Mean Acute Value (SMAV) used to represent the laboratory water toxicity endpoint value in the WER equation. The value of 19.31 is specific to the hardness concentration term of “100” in the numerator of the term “100/Hardness”. The term “0.9422” (the exponent to the term “100/Hardness”) is the acute copper criteria hardness slope and is used to normalize a subject water sample to the same hardness concentration (100 mg/L) as the 19.31 SMAV.

STATEMENT OF BASIS FOR AMENDEMENT

Chino petitions the Commission to adopt the site-specific criteria, in accordance with 20.6.4.10(D)(3) NMAC, to adjust the aquatic and wildlife criteria for copper for the portions of

the surface waters identified above. The following information is provided in accordance with that provision:

(a) identify the specific waters to which the site-specific criteria would apply:

This site-specific aquatic life criteria for copper shall apply only to certain surface waters located in the Mimbres River Closed Basin and also within an area known as the Chino Mines Site STSIU and described as follows:

- (a) the mainstem of Lampbright Draw beginning at the confluence of Lampbright Draw with Rustler Canyon to the intersection of Lampbright Draw with the southern STSIU boundary and all tributaries thereof that originate west of Lampbright Draw, including Rustler Canyon and Martin Canyon;
- (b) Lucky Bill Canyon and all tributaries thereof;
- (c) Chino Mines property Subwatershed Drainages A, B, C, D-1, D-2, D-3 and all tributaries thereof; and
- (d) Chino Mines property Subwatershed Drainages E-1, E-2, and E-3.

These surface waters are shown on the map attached to this Petition as Exhibit "A".

(b) explain the rationale for proposing the site-specific criteria:

The portions of the waters identified above are within a study area known as the Chino STSIU and are the subject of investigation under an Administrative Order on Consent between Chino and the New Mexico Environment Department ("NMED") dated December 23, 1994 ("AOC"). The investigation identified elevated copper in soils as the primary contaminant of concern in this area, some of which may be from a combination of historic smelter emissions and blowing copper mill tailings. Surface-water sampling conducted as part of the investigation indicated exceedances of the current hardness-based aquatic life criteria for copper in drainages located in this area. Under the AOC, NMED has conducted an ecological risk assessment with respect to copper in the soils and has issued "pre-Feasibility Study Remedial Action Criteria" ("pre-FS RAC") with respect to the soils and surface waters, including potential impacts on aquatic life in the ephemeral and non-ephemeral surface waters. The pre-FS RAC for surface

waters requires compliance with the State of New Mexico Standards for Interstate and Intrastate Surface Waters, 20.6.4 NMAC, for risk to aquatic life in the drainages of the STSIU including all approaches and tools listed in the Rules which provide options for site-specific application.

In connection with the AOC investigation, Chino proposed to evaluate potential site-specific criteria for copper for surface waters in the STSIU. All of the surface waters which are the subject of this petition are “unclassified” waters subject to use designations under 20.6.4.97, .98 or .99 NMAC, as applicable. Those waters subject to 20.6.4.98 NMAC (intermittent waters) will have the relevant designated use of “marginal aquatic life”, and those waters subject to 20.6.4.99 NMAC (perennial waters) will have the relevant designated use of “warmwater aquatic life.” Some of the waters to which the site-specific copper criteria adjustment proposed in this petition would apply are proposed to be treated as “ephemeral” under NMED’s proposed amendments to 20.6.4.97 NMAC, as set forth in NMED’s petition. If the Commission adopts NMED proposed amendments to 20.6.4.97 NMAC, then the waters covered by that amendment will have the designated use, as relevant for this petition, of “limited aquatic life.” The applicable use designations under 20.6.4.97, .98 and .99 NMAC are not affected by this petition. The proposed site-specific WER adjustment, however, is intended to apply regardless of the particular aquatic life use designation under 20.6.4.97, .98 or .99 NMAC.

Under the relevant criteria specified in 20.6.4.900 NMAC, numerical aquatic-life criteria for copper are derived using a formula that considers the hardness of the water. A variety of other physical and non-hardness chemical characteristics of the water and the metal can influence metal bioavailability and toxicity to aquatic organisms, as recognized by the U.S. EPA (U.S. EPA Water Quality Standards Handbook, EPA-823-B-94-005a, 2nd edition, August 1994). These parameters include suspended and dissolved solids, pH, alkalinity, organic carbon

compounds, ionic strength and other characteristics, which can have equal or greater effects on copper toxicity than hardness alone.

This Petition is based upon work completed from 2011 through 2014 that has been reviewed and commented on by NMED. In September 2011, Chino submitted a proposed Study Work Plan to NMED to utilize the water effect ratio (“WER”) method to develop site-specific criteria, a method identified in 20.6.4.10(D)(4)(a)-(b) NMAC. The Study Work Plan and subsequent technical documents were distributed to the NMED Surface Water Quality and Ground Water Quality Bureaus and to the U.S. Environmental Protection Agency, Region 6, AOC project managers and its Water Quality Standards Coordinator. The Study Work Plan proposed sampling locations and frequency to gather relevant chemical data, proposed laboratory methods of analysis, identified some changes in the general methodology due to the nature of the site, and proposed the development of a model to be used to derive proposed site-specific criteria. NMED provided written comments requesting the addition of more sampling locations and increased sampling frequency and acknowledged the need for methodology changes to address the site-specific circumstances. Chino incorporated the changes to the Study Work Plan recommended by NMED and initiated the study.

Chino and NMED met in March 2012 to discuss the sampling and analytical results and the initial model development, including the selection of model parameters, the methods for model application and the production of an interim report containing all of the data. A draft interim report was submitted to NMED for review in October 2012, and NMED provided comments in December 2012. In March 2013 Chino submitted a revised interim report addressing NMED’s comments and subsequently submitted a draft site-specific model report in April 2013. NMED provided comments in July 2013 and Chino submitted a final report in

October 2013 entitled “Revised Site-Specific Copper Toxicity Model Report.” A copy of the text of that report is attached as Exhibit “B.” Copies of the complete report including tables, figures, and appendices containing data and related evaluations are available at the following web link: <http://www.fcx.com/chino/pdf/2013/100313.pdf>. This Petition is based upon the information presented in the final report.

The study methodology and general results were published in a peer-reviewed scientific journal, “Environmental Technology and Chemistry”: *B.A. Fulton and J.S. Meyer*, “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,” Vol. 33, No. 8 pp. 1865-1873 (2014). A copy of this paper is attached as “Exhibit C.”

(c) describe the methods used to notify and solicit input from potential stakeholders and from the general public in the affected area, and present and respond to the public input received:

Chino implements a public participation process according to a Community Relations Plan under the AOC. The process includes public meetings with a Community Working Group (CWG) at which NMED and Chino present and discuss activities conducted under the AOC. The CWG holds regular meetings, in Bayard or Hurley, New Mexico and is composed of interested public stakeholders. Participation in CWG is open to all interested community members. Starting in 2011, NMED informed the CWG of Chino’s efforts to develop site-specific copper criteria in drainages associated with the STSIU, and this is documented in NMED’s AOC document status handouts and CWG meeting minutes.

Chino provided public notice of the September 16, 2014, CWG meeting in the local newspaper of record (Silver City Daily Press) in both English and Spanish on September 2, 2014 and September 15, 2014. The public notice included information about the site-specific

copper criteria presentation and the web address for Chino's online document website repository. The website contains a link to the October 2013 Revised Site Specific Copper Toxicity Model Report. NMED included copies of the same report in the Chino AOC document physical repositories located in Silver City, Bayard and Santa Fe prior to the September 16, 2014 CWG meeting. On September 11, 2014, Chino provided email notification of the CWG meeting to CWG members and NMED. At the September 16, 2014, CWG meeting held at the Bayard Community Center, Bayard, New Mexico, Chino's technical expert and consultant Barry A. Fulton of ARCADIS provided a detailed presentation to the CWG on the development of the Site-Specific Copper Toxicity Model for the STSIU drainages. At that meeting, NMED and Chino answered questions from the public, and invited public comment on the model report and proposed criteria.

(d) present and justify the derivation of the proposed criteria:

The Commission may adopt site-specific numeric criteria applicable to all or a part of a surface water of the state based upon relevant site-specific conditions under 20.6.4.10(D)(1) NMAC. The relevant site-specific conditions include "physical or chemical characteristics at a site such as pH or hardness alter the biological availability and/or toxicity of the chemical." 20.6.4.10(D)(1)(b) NMAC. Site-specific criteria must fully protect the designated use to which they apply. 20.6.4.10(D)(2) NMAC. A derivation of site-specific criteria shall rely on a scientifically defensible method, such as one of those listed in 20.6.4.10(D)(4)(a)-(e) NMAC.

Under the relevant criteria specified in 20.6.4.900 NMAC, numerical aquatic life criteria for copper are derived using a formula that considers the hardness of the water. A variety of other physical and non-hardness chemical characteristics of the water and the metal can influence metal bioavailability and toxicity to aquatic organisms, as recognized by the U.S. EPA

(U.S. EPA Water Quality Standards Handbook, EPA-823-B-94-005a, 2nd edition, August 1994).

These parameters include suspended and dissolved solids, pH, alkalinity, organic carbon compounds, ionic strength and other characteristics, which can have equal or greater effects on copper toxicity than hardness alone.

To account for the effects that water chemistry has on metal toxicity, site-specific criteria may be developed using the WER procedure (20.6.4.10(D)(4)(a)-(b) NMAC). The WER procedure consists of site-water toxicity tests conducted side-by-side with laboratory-water toxicity tests, and is used to specifically account for differences between toxicity of the metal in laboratory dilution water (results of which were used to derive the copper criteria in 20.6.4.900 NMAC) and toxicity of the metal in STSIU waters that can be attributed to site-specific chemistry.

Chino used the interim WER procedure for metals (published by the U.S. Environmental Protection Agency, EPA-823-B-94-001 (February 1994)) and the streamlined WER procedure for discharges of copper (published by the U.S. Environmental Protection Agency, EPA-822-R-01-005 (March 2001)) identified in 20.6.4.10(D)(4)(a)-(b) NMAC to derive the proposed criteria. A description of the methodology used, the adjustments to reflect site-specific conditions, the basis for the methodology and the adjustments, the data collected and used to develop the proposed site-specific standard, and the calculations used to derive the proposed site-specific standard all are documented in the report attached as Exhibit "B."

The proposed WER model was selected based on statistical relations between Site chemistry and measured toxicity and by linking these relations to the dominant mechanisms of copper toxicity that occur within the specific range of STSIU water chemistries. From a statistical standpoint, the proposed model was determined as the best-fit model based on its

rigorous multi-linear regression (MLR) analysis and its accuracy. The MLR model approach was determined to provide better predictions than a model using only water hardness, without systematically over- or under-predicting toxicity values, while also covering wide temporal and spatial conditions found in STSIU waters. Recommendations for using this model were also based on an understanding of the hydrology, upland properties, nature and extent of potential contamination, and surface-water chemistry that is known to occur throughout the STSIU study area.

After using the best-fit multi-linear regression (MLR) model to evaluate water samples in the STSIU study area, it was determined that the combination of DOC and alkalinity is the biggest driver in predicting copper toxicity within STSIU surface waters. The relationship between DOC and alkalinity provides a highly predictive tool for estimating site-specific copper toxicity based on using measured water chemistry values as input parameters to a predictive Site-specific copper model.

Compared to the current hardness-based copper criteria, the MLR model approach considers the effects of multiple water chemistry parameters on site-specific copper toxicity. This provides a more accurate estimate of copper toxicity across STSIU waters because other toxicity-modifying parameters than only water hardness are accounted for. As a result, the site-specific MLR approach can reduce uncertainty about the over-protectiveness or under-protectiveness of the current hardness-based criteria, or uncertainty associated with application of other site-specific criteria options such as the BLM or a traditional WER approach. Additionally, because this approach accounts for water chemistry variability by adjusting the numeric value of the site-specific criterion as a function of the water chemistry for each water sample, it is consistent with the current hardness-based approach. Further, the specific

implementation steps and margin of safety incorporated into the proposed criteria for applying site-specific criteria to STSIU waters provides a technically-defensible basis to address site-specific challenges, while also providing for environmentally conservative site-specific criteria.

The results of the application of this method, based upon the site-specific data, is the formula as stated in the proposed rule language. If the Commission incorporates this language into the surface water quality standards, this formula will be used to determine numerical copper limits only for the specific waters for which the site-specific standard is adopted.

CONCLUSION

For the reasons stated above, and in accordance with 20.6.4.10(D) NMAC, Chino respectfully requests that the Commission adopt the site-specific criteria set forth in this Petition and incorporate it into 20.6.4 NMAC. Chino will present testimony and additional evidence in support of this Petition at the hearing in accordance with the Scheduling Order and the Procedural Order in this matter.

Respectfully Submitted,

GALLAGHER & KENNEDY, P.A.



Dalva L. Moellenberg
Germaine R. Chappelle
1233 Paseo de Peralta
Santa Fe, NM 87501
Phone: (505) 982-9523
Fax: (505) 983-8160
DLM@gknet.com
germaine.chappelle@gknet.com

CERTIFICATE OF SERVICE

I hereby certify that a true and accurate copy of the foregoing pleading was hand-delivered to the following parties on Tuesday, September 30, 2014:

Kevin J. Powers
Assistant General Counsel
Office of General Counsel
New Mexico Environment Department
1190 St. Francis Drive
Santa Fe, New Mexico 87502-6110
Phone: 505-827-2885
Email: kevin.powers@state.nm.us
For the New Mexico Environment Department

Pam Castaneda
Administrator
New Mexico Environment Department
1190 St. Francis Drive
Santa Fe, New Mexico 87502-6110
Phone: 505-827-2425
Email: pam.castaneda@state.nm.us


Germaine Chappelle



Chino Mines Company
Box 10
Bayard, NM 88023

October 4, 2013

Certified Mail #70122210000106174271
Return Receipt Requested

Kris Pintado, Standards Team Leader
New Mexico Environment Department
Surface Water Quality Bureau
P.O. Box 5469
Santa Fe, New Mexico 87502

Re: Revised Site-Specific Copper Toxicity Model Report
Smelter Tailings Soils IU Drainages – Chino Administrative Order on Consent

Dear Ms. Pintado:

Freeport-McMoRan Chino Mines Company (Chino) submits the attached *Revised Site-Specific Copper Toxicity Model Report* for New Mexico Environment Department (NMED) Surface Water Quality Bureau (SWQB). Chino submitted a draft of this report in April 2013 to NMED and subsequently made revisions to the report in response to comments received from SWQB in a letter dated July 1, 2013. Also attached in a separate document is Chino's response to SWQB's comments.

This report contains the additional data analysis as discussed in, and as follow up to the *Development of Site-Specific Copper Criteria Interim Report* submitted to NMED on March 22, 2013. The Interim Report provides a summary of all data collected in accordance with methods described in the work plan titled *Development of Site-Specific Copper Criteria* submitted in August 2011 to NMED that described proposed studies to support development of site-specific copper criteria in the Smelter and Tailing Soil Investigation Unit (STSIU) surface waters. These reports address drainages associated with the STSIU subject to the Chino Administrative Order on Consent, supporting the development of site-specific copper criteria for surface waters. This attached revised report describes the development of a site-specific copper Water Effects Ratio model that can potentially be used to predict and derive adjusted copper criteria in STSIU surface waters.

Please contact Ned Hall at (520) 393-2292 with any questions concerning this revised report.

Sincerely,

Sherry Burt-Kested, Manager
Environmental Services

SBK:pp
Attachments
20131003-001
Attachment

c. w/ attachment
Bryan Dail, NMED SWQB
Joseph Fox, NMED GWQB
Matthew Schultz, NMED GWQB
Russell Nelson, US EPA
Ned Hall, FCX Copper & Gold Inc.
Pam Pinson, FCX, Chino

c. w/o attachment
Petra Sanchez, US EPA
James Hogan, NMED SWQB
Shelly Lemon, NMED SWQB
Dave Menzie, NMED SWQB

Exhibit

Site-Specific Copper Toxicity Model Report



Chino Mine Site

**Freeport-McMoRan Chino Mines Company – Administrative Order on Consent
Response to New Mexico Environment Department Comments dated July 1, 2013
Draft Site-Specific Copper Toxicity Model Report
Smelter and Tailing Soils Investigation Unit (STSIU) Drainages
October 4, 2013**

This document presents responses by Freeport-McMoRan Chino Mines Company (Chino) to comments from the New Mexico Environment Department (NMED) Surface Water Quality Bureau (SWQB) on the Draft Site-Specific Copper Toxicity Model Report for the Smelter/Tailing Soils Investigation Unit (STSIU) Drainages, dated July 1, 2013. The Draft Site-Specific Copper Toxicity Model Report, dated March 2013, was prepared to support the development of site-specific copper criteria that can be applied to STSIU surface waters, pursuant to Section 20.6.4.10 part D of the New Mexico Administrative Code (NMAC). This letter is organized to present a response to each general comment received from NMED.

NMED Comment #1: The results of regression analysis and the model proposed present a significant improvement on predicting Cu toxicity at the STSIU and thus seem suitable for development of a Cu SSC. While the report is not explicit, it appears that this model was selected based primarily on the very impressive R^2 . We suggest the final analysis should consider other approaches and more broadly consider what would be the most appropriate SSC. For example, it was discussed in the meeting how the model uses the ratio of hardness to alkalinity, not the measured concentrations. While the use of a ratio works for the data collected in this report, it may not apply to lower alkalinity waters which have a similar ratio as they will not have a similar protection from Cu toxicity. As such, if this model is adopted it may be appropriate to specify that it only applies to the range of alkalinity observed in this study.

Chino Response #1: Chino appreciates the feedback regarding possible approaches for deriving site-specific criteria (SSC). The initial regression model, which included total organic carbon (TOC), hardness/alkalinity ratio, and total dissolved solids (TDS) as model input parameters, was selected based primarily on its R^2 value and by considering how each parameter is mechanistically related to aqueous copper bioavailability and toxicity. **Section 3.2.4** of the revised report provides a more formal discussion of the various statistical criteria and chemistry relationships considered when evaluating and selecting a multiple-regression model.

Based on discussions with NMED SWQB during the June 10, 2013 meeting in Santa Fe, New Mexico concerning additional statistical evaluations and on the above comment regarding low alkalinity concentrations, Chino proposes a new regression model that uses dissolved organic carbon (DOC) and alkalinity as the model input parameters in the revised report. This new model is equivalent in terms of predictability compared to the initial model described above which used TOC, hardness/alkalinity, and TDS as input parameters. Additionally, this new proposed model appears to be more reliable based on the variance and model structure (i.e., similar predictive capability using fewer input parameters) and it is consistent with the NMED suggestion to not use the hardness/alkalinity ratio in the regression model. **Section 3.2.4** of the revised report describes how using measured concentrations of alkalinity instead of the hardness/alkalinity ratio addresses uncertainty about low alkalinity concentrations and/or similar hardness/alkalinity ratios that can be derived from differing alkalinity concentrations.

Site-Specific Copper Toxicity Model Report



Chino Mine Site

The revised water effect ratio (WER) model was selected based on a step-wise multiple linear regression analysis that evaluated relationships between different combinations of water chemistry parameters and copper toxicity (Section 3.2.4 and Table 3 of the report). Other possible approaches including the copper biotic ligand model (BLM) (Section 3.2.5), hardness-based criteria (Section 3.2.1), and application of a static WER to derive SSC (Section 4.1) were evaluated and compared to the proposed approach in the revised report. The general WER model approach described herein, and the specific regression model selected for this approach (DOC and alkalinity), were determined to provide the most accurate and reliable predictions of Site-specific copper toxicity based on this comparison. The margin of safety recommendations to the proposed approach (i.e., use of the *D. magna* SMAV as the WER denominator and treatment of input parameters that are either above or below the range used to develop the model described in Section 4.2.2) ensures that SSC are derived in an environmentally conservative way.

NMED Comment #2: Another approach discussed is to adjust the BLM which presently is systematically under-protective. Again, the suggestion here is not that one of these options is better than the model proposed in the draft report but simply that these alternatives should be evaluated to provide confidence that the proposed model is the most scientifically defensible.

Chino Response #2: As described Section 3.2.5 of the revised report, Chino does not recommend using a modified BLM (or the BLM "out of the box") to derive site-specific copper criteria for STSIU surface waters. Currently, the options for adjusting the BLM only affect the toxicity-prediction mode application. The program files used in the BLM's criteria calculation option are not publicly available. Although it is possible to request access to these files per Dr. Joe Meyer during the June 10, 2013 meeting, the acceptability of this approach is questionable since calculations would not be reproducible by others, and because these potential adjustments could be inconsistent with EPA's intended use of the BLM for copper criteria calculations. Based on the evaluations presented in the revised report and discussed during the June 10, 2013 meeting, adjusting the BLM to systematically change the predictions is not expected to provide greater predictability compared to the regression-model approach. Section 3.2.5 of the revised report provides additional discussion of the copper BLM.

NMED Comment #3: The Cu model presented in the report addresses site specific challenges, and reduces the uncertainty associated with other approaches including hardness-based criteria and the BLM, however further detail regarding the implementation of the model to develop criteria recommendations for STSIU surface waters is also necessary. For example, given that water was only collected from perennial pools and not stormwater, the SWQB assumes that the SSC only applies to the chronic Cu criteria, and not the acute. Likewise, SWQB assumes that the geographic extent to which SSC would apply only includes those drainages from which water was collected.

Chino Response #3: Section 4.2 of the revised report provides details regarding the implementation of the model to derive and apply SSC to STSIU waters. That section specifically describes step-by-step how to apply the proposed WER model to derive a SSC, discusses the applicability of the approach to acute and chronic SSC, and proposes the geographic extent for model application. Based on discussions provided in Section 4.2, a brief summary of the recommendations for model implementation and applicability follows.

Site-Specific Copper Toxicity Model Report



Chino Mine Site

- **Model Implementation:** The proposed approach for using the WER model to derive and apply SSC to STSIU waters was developed based on available WER guidance and based on current procedures for calculating and applying the current hardness-based copper criteria. The recommendation is to apply the model on a sample-by-sample basis (similar to the hardness-based criteria approach) to derive a SSC and evaluate compliance for a given sample. This is accomplished by applying the WER model to the measured DOC and alkalinity concentrations from a sample to calculate a SSC. Compliance is then evaluated by comparing the measured copper concentrations from that sample to the derived SSC.
- **Application to Acute and Chronic Criteria:** Based on USEPA WER guidance, the proposed approach can be used to derive both acute and chronic criteria. Water samples used in the WER toxicity tests were collected from ephemeral pools associated with monsoon storm water runoff and from intermittent and perennial pools; all WER toxicity tests were performed using the acute *Daphnia magna* toxicity test procedure. The USEPA WER guidance states that a WER derived from acute toxicity tests can be applied to both acute and chronic criteria. The protectiveness against toxicity (and thus the value of the WER) is determined by the water chemistry, not by the length of time surface water exists within a given drainage. **Section 4.2.1** of the revised report provides additional discussion of model application to acute and chronic criteria.
- **Geographic Extent of Model Application:** Chino believes the proposed regression-based model can be applied to all of the STSIU drainages, provided the water chemistry is similar to the water chemistry range from which the model was developed (see discussions in **Section 4.2.2.3** of the revised report). Chino does not believe that a model developed for STSIU waters should be applied to the adjacent Hanover-Whitewater Creek (HWC) drainage system because water chemistry in HWC differs from water chemistry in the STSIU waters, and because the geomorphology, hydrology and surrounding uplands also differ from the STSIU study area. In contrast, because the model is developed from only STSIU samples collected from locations with relatively similar hydrology, geomorphology and upland vegetation characteristics, it can be applied to all drainages in the STSIU study area. Given the strong statistical relationship demonstrated between water chemistry and toxicity results, there is high confidence that "predicted" results derived from the model are applicable to all of STSIU drainage locations. Furthermore, the evaluation of STSIU chemistry ranges presented in **Appendix E** shows that chemistry ranges used to develop the proposed model are representative of surface water chemistry ranges measured to date in the STSIU area.

NMED Comment #4: We also recommend the final report address not only the adjustment of the Cu criteria based on SSC – but also consider specific aquatic species that are present in the watershed, and their sensitivity to Cu to ensure that the revised standard is sufficiently protective. The final report should consider the results of the 2008 USGS study by Little and Calfee, submitted to the US Fish and Wildlife Service, which examined the toxicity of metals to the Chiricahua leopard frog. The study recorded Lowest Observed Effect Concentrations from the 60-day "chronic" tests for copper at 0.047 mg/L for development and length, and 0.007 mg/L for weight. Therefore, the Chino Mines study

**Site-Specific Copper
Toxicity Model Report**



Chino Mine Site

should consider whether the proposed regression model is consistent with these results, or otherwise address whether the regression model, if applied to these waters, would be protective of developmental stages of Chiricahua leopard frog. It is noted that while the Little and Calfee (2008) report does not provide information on TOC concentrations the TDS, alkalinity and hardness values are all within the range of waters collected from the STISU.

Chino Response #4: Appendix F of the revised report evaluates the protectiveness of the proposed WER model approach to the Chiricahua leopard frog (CLF), based on the copper effect concentrations reported in Little and Calfee (2008). In summary, **Appendix F** shows that the proposed approach is protective of CLF developmental stages. This conclusion is based on applying the proposed model to the water chemistry values measured during the 60-day copper exposures and determining that the derived SSC is less than all effect concentrations reported by Little and Calfee (2008). Although organic carbon concentrations were not measured or reported in Little and Calfee (2008), Little et al. (2011) reported DOC concentrations of 0.2 to 0.5 mg/L from the same laboratory and during the same time period for a similar mixture of well water and deionized water. Therefore, these DOC concentrations were used to calculate SSC from the new proposed model (which uses DOC and alkalinity to predict toxicity and thus WERs) to compare to the reported CLF effect concentrations. This comparison is the primary basis for concluding that the proposed approach will be protective of developmental stages of the CLF. In **Appendix F**, Chino also provides an evaluation of the study design and applicability of reported effect concentrations in Little and Calfee (2008) to identify possible uncertainties associated with the reported effect concentration in order to fully compare the protectiveness of the proposed WER model to the sensitivity of the CLF. This evaluation further supports Chino's conclusion that the proposed approach is protective to the CLF.

NMED Comment #5: Finally, Chino Mines suggested that they may submit the final report for external scientific review and publication. Given the unique approach presented in the draft report, SWQB supports publication in peer reviewed scientific literature as it will strengthen the basis for SSC in the STISU.

Chino Response #5: Chino plans to submit the study results and the proposed WER model report for scientific review and publication by the end of 2013, following SWQB's review of this revised report. Based on this schedule, Chino expects final approval from the journal in April 2014.

Freeport-McMoRan Chino Mines Company

**Revised Site-Specific Copper
Toxicity Model Report**

Chino Mine, Vanadium, New Mexico

October 2013



Derek Edge

Derek Edge
National Technical Manager

Joseph A. Meyer

Joseph Meyer
Technical Expert

Barry Fulton

Barry Fulton
Senior Scientist

**Revised Site-
Specific Copper
Toxicity Model
Report**

Prepared for:
Freeport-McMoRan Chino Mines
Company

Prepared by:
ARCADIS

Tel: 303-231-9115 ext.109
Fax: 303-231-9571

Our Ref.:
B0063543.0006

Date:
October 2013

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Acronyms and Abbreviations

| | |
|--------|--|
| ACZ | ACZ LABORATORIES, INC. |
| AOC | Administrative Order on Consent |
| AWWQRP | Arid West Water Quality Research Project |
| BLM | Biotic Ligand Model |
| CCC | Criterion Continuous Concentration |
| COC | Chain of Custody |
| Chino | Freeport-McMoRan Chino Mines Company |
| CMC | Criterion Maximum Concentration |
| DOC | Dissolved Organic Carbon |
| DOM | Dissolved Organic Matter |
| EC50 | Median Effect Concentration |
| FS | Feasibility Study |
| GEI | GEI Consultants, Inc. |
| IA | Investigation Area |
| LA50 | Lethal Accumulation Concentration |
| LC50 | Median Lethal Concentration |
| MDL | Method Detection Limit |
| MLR | Multiple Linear Regression |
| NMAC | New Mexico Administrative Code |
| NMED | New Mexico Environment Department |
| pH | Negative of the logarithm of the hydrogen ion concentration (standard units) |
| RAC | Remedial Action Criteria |
| RI | Remedial Investigation |
| SSC | Site-Specific Criteria |
| SWQB | Surface Water Quality Bureau |
| STSIU | Smelter/Tailing Soil Investigation Unit |
| TDS | Total Dissolved Solids |
| TOC | Total Organic Carbon |
| TSS | Total Suspended Solids |



Acronyms and Abbreviations

| | |
|-------|---|
| UAA | Use Attainability Analysis |
| USEPA | United States Environmental Protection Agency |
| VIF | Variance Inflation Factor |
| WER | Water-Effect Ratio |
| WQC | Water Quality Criteria |



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1. Introduction and Background

On December 23, 1994, Freeport-McMoRan Chino Mines Company (Chino) and the New Mexico Environment Department (NMED) Surface Water Quality Bureau (SWQB) entered into an Administrative Order on Consent (AOC) to investigate historical releases of potentially hazardous substances within the Chino Mine Investigation Area (IA), Grant County, New Mexico (the Site). The Smelter and Tailing Soil Investigation Unit (STSIU) is one of the investigation units within the defined IA. By letter dated September 16, 2010, NMED specified the Pre-Feasibility Study (FS) Remedial Action Criteria (RAC) for the STSIU. As one of the Pre-FS RAC, NMED required compliance with New Mexico Standards for Interstate and Intrastate Surface waters, 20.6.4 New Mexico Administrative Code (NMAC) for risk to aquatic life for drainages within the STSIU. The letter states that Pre-FS RAC for all constituents equal 20.6.4 NMAC, including all approaches and tools listed in the Code that provide options for site-specific application.

Copper is the primary contaminant of concern in STSIU, and surface water in some STSIU drainages has been determined to exceed the aquatic life water quality criteria in 20.6.4 NMAC before consideration of the approaches and tools that provide for site-specific application. In particular, in accordance with Section 20.6.4.900 NMAC, water quality criteria for copper (and other divalent cationic metals) are calculated using a standard equation based exclusively on site-specific water hardness. Previous Site investigations, including the Site-wide ERA (Newfields 2005) and STSIU Remedial Investigation (RI) indicated exceedances of current hardness-based copper criteria in sub-drainage basins within the STSIU area. However, a variety of other physical and non-hardness chemical characteristics of the water and the metal can influence metal bioavailability and toxicity to aquatic organisms (U.S. Environmental Protection Agency [USEPA] 1994, 2001, 2007). Multiple studies have demonstrated other water quality parameters such as suspended and dissolved solids, pH, alkalinity, organic carbon compounds, ionic strength and other characteristics have equal or greater effects on copper toxicity than hardness alone (AWWQRP 2006, Meyer et al. 2007).

To account for the effects water chemistry has on metal toxicity, site-specific criteria (SSC) may be developed using scientifically defensible methods that are described in Section 20.6.4.10 part D of NMAC, which includes the Water-Effect Ratio (WER) procedure. The WER procedure consists of site-water toxicity tests conducted side-by-side with laboratory-water toxicity tests, and is used to specifically account for differences between toxicity of the metal in laboratory dilution water and toxicity of the metal in Site water that can be attributed to site-specific water chemistry. If there is a difference in toxicity and it is not taken into account, the aquatic life criteria for the tested body of water might be either more or less protective than intended by EPA's



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Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses (USEPA 1994).

1.1 Historical Background of STSIU WER Studies

In August 2011 on behalf of Chino, ARCADIS submitted a work plan titled *Development of Site-Specific Copper Criteria* (ARCADIS 2011) to the NMED Surface Water Quality Bureau (SWQB) that described proposed WER studies to support the development of site-specific copper criteria in STSIU surface waters. SWQB provided comments to the work plan in a letter dated September 1, 2011. The WER studies were subsequently conducted, and a summary of preliminary results and the WER multiple-regression model approach described in the work plan was presented to NMED SWQB during a March 23, 2012 meeting in Albuquerque, NM. These results were further evaluated against USEPA (1994, 2001) WER acceptability criteria and fully reported in the draft *Criteria Adjustment Interim report* that was submitted to NMED SWQB in October 2012 (ARCADIS 2012). Chino received NMED comments to that report in December 2012, and submitted responses to those comments and a revised *Interim Report* to NMED SWQB in March 2013 (ARCADIS 2013a).

As described in the above work plan and *Interim Report*, and acknowledged by NMED comments to the work plan, a modified approach is required to develop and apply SSC to STSIU surface waters because the site-specific hydrologic conditions and contaminant sources at STSIU are not explicitly addressed in the available USEPA WER guidance. The use of multiple-regression analysis of co-located toxicity and water chemistry data explicitly accounts for the effects of site-specific water chemistry on copper bioavailability and toxicity and can also address the site-specific challenges described in the work plan. The technical basis of this approach, including statistical evaluations, application of available USEPA guidance, and consideration of the mechanisms of copper bioavailability and toxicity, was initially described in the draft *Copper Toxicity Model report* submitted to NMED SWQB in April 2013. Chino and NMED SWQB subsequently met in Santa Fe, NM on June 10, 2013 to discuss the WER model approach described in that report. The current report has been updated based on discussions with NMED SWQB during the June 10, 2013 meeting and based on comments received from NMED SWQB to the draft *Copper Toxicity Model report* in a letter dated July 1, 2013.

1.2 Study Objectives

This report describes the development of a site-specific copper WER model that can potentially be used to predict and derive adjusted copper criteria in STSIU surface waters. As described previously, a modified approach is required to develop and apply SSC to STSIU surface waters because site-specific STSIU conditions are not

specifically covered in the available USEPA WER guidance documents (USEPA 1994, 2001). These site-specific conditions include diffuse, nonpoint-source copper contamination to multiple ephemeral drainage channels that typically flow only in direct response to monsoonal precipitation. As a result, almost all aquatic habitats in STSIU consist entirely of isolated pools located in predominately bedrock sections of drainage channels. Additionally, water chemistry has been observed to be variable across the numerous STSIU sub-watersheds because of localized differences in geology, geomorphology, hydrology, and surrounding upland landscapes among the sub-watersheds.

The interim report (ARCADIS 2013a) established that toxicity and chemistry data collected during WER sampling in 2012 were acceptable for use in the development of SSC for copper. WERs determined during that sampling and analysis effort were mostly greater than 1, indicating that the current hardness-based copper criteria are overprotective of aquatic life uses in the STSIU samples used for WER testing. Additionally, the Interim Report demonstrated that site-specific copper toxicity and copper WERs were variable across the STSIU watersheds. It was hypothesized in the Interim Report that the toxicity variability could be largely explained by the variability in water chemistry samples used for testing.

The primary objective of this report is to further evaluate site-specific copper toxicity and water chemistry data reported in ARCADIS (2013a) by performing statistical evaluations of the chemistry and toxicity variability to determine specific chemical parameters that are most correlated with the observed toxicity. Based on these evaluations, the second objective of this report is to describe a site-specific copper WER model that can explicitly account for this variability, and thus can potentially be used to develop and apply SSC to STSIU watersheds.

2. Methods

Field and laboratory methods employed in this study were described in ARCADIS (2013a) and were consistent with methods described in the available WER guidance documents. A brief summary of the field and laboratory methods as reported in ARCADIS (2013a) follows.

Field sampling and laboratory testing occurred twice during the wet season in 2011. WER samples were collected in eight different sub-watersheds; these samples were collected during two separate sampling rounds in 2011. The first round of field sampling was performed during 29 August – 2 September, 2011 and included 12 WER samples; the second round of field sampling was conducted during 19 – 20 September 2011 and included six WER samples. **Figure 1** presents the location of all samples collected during both rounds of WER sampling. Flow was not observed in any



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drainage during the field sampling; all water samples were collected from isolated, surface-water pools present in bedrock or primarily bedrock sections of drainage channels. In total, 18 WER samples were collected from 12 distinct sampling locations located across eight sub-watersheds (Figure 1). In addition to subsamples of those waters, six additional water samples were submitted for chemical analyses (i.e., these six additional samples were not used in the WER toxicity tests) during the two rounds of sampling. As noted in ARCADIS (2013a), sample locations were limited to drainage areas containing surface water. The majority of drainage areas surveyed were dry during each sampling round. At each of the 12 water-sampling locations for WER toxicity tests, surface-water samples were split at the time of collection and a portion of each split sample was sent directly from the field to ACZ Laboratories, Inc. (ACZ) in Steamboat Springs, Colorado, for chemical analyses; the other portion of the split sample was sent directly from the field to GEI Consultants, Inc. (GEI) in Denver, Colorado, for WER toxicity tests. Samples were collected, shipped, and stored according to methods described in ARCADIS (2011) and USEPA (1994, 2001), which included "clean sampling techniques", chain-of-custody (COC) forms and USEPA protocols for toxicity testing.

WER toxicity tests were conducted by GEI using less than 24-hour-old neonates of the freshwater cladoceran *Daphnia magna* (an invertebrate) as the primary test species. WER toxicity tests were also conducted on a subset of samples using less than 24-hour-old larvae of the fathead minnow (*Pimephales promelas*; a freshwater fish) as the secondary test species. The major use of the secondary species, as described by USEPA (1994), is confirmation of toxicity results obtained with the primary species. Use of a secondary species, however, was omitted from the more recent USEPA Streamlined WER Guidance because "the additional test has not been found to have value" (USEPA 2001: p. 5). Instead, the Streamlined Procedure requires that either *Ceriodaphnia dubia* (another freshwater cladoceran) or *D. magna* be used as the tested taxon because "experience has shown that the daphnids, which are quite sensitive to copper, have been the most useful test organisms for WER studies" (USEPA 2001: p. 5). As described in ARCADIS (2013a), results from the secondary test species (the fathead minnow) confirmed results obtained with the primary test species (*D. magna*) according to WER acceptability criteria presented in USEPA (1994). This report therefore focuses evaluations on the *D. magna* copper toxicity endpoints because it was identified, and validated, as the primary test organism.

Toxicity test procedures followed methods described in USEPA WER guidance (USEPA 1994, 2001) and general whole-effluent acute-toxicity testing methodology (USEPA 2002). Test conditions are listed in Appendix A. Stock solutions of copper were prepared by dissolving $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ in deionized water. A separate stock solution was prepared for each round of WER testing, but the same stock solution was used to spike all laboratory and STSIU waters in each round of testing. Results from 24-hour



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range-finding toxicity tests (conducted for each STSIU water sample) were used to select the copper exposure concentrations in the WER toxicity tests. Total recoverable and dissolved concentrations of copper were measured in each exposure treatment required to calculate the toxicity endpoint, consistent with USEPA (1994, 2001) WER protocols. Total and dissolved copper were measured at the beginning and end of each 48-hour *D. magna* toxicity test. WER guidance requires dissolved metal analysis at the beginning and end of toxicity tests, but only requires total metal analysis for exposure water samples collected at the beginning of tests. Total copper was measured on samples collected at the beginning and end of toxicity tests to provide an additional verification of copper exposure concentrations. Samples for dissolved-metals analyses were filtered in GEI's laboratory using a 0.45-micrometer (μm) filter. The samples were preserved after filtration and shipped to ACZ for analysis.

Toxicity tests using STSIU surface waters were conducted side-by-side with toxicity tests using standardized laboratory dilution water according to USEPA protocol (USEPA 1994, 2001). As described by USEPA (1994), more than one toxicity test using site water may be conducted side-by-side with a single laboratory dilution water. However, multiple laboratory dilution-water toxicity tests were conducted in this study to encompass the range of water hardness in STSIU waters and because toxicity tests were staggered across multiple days in each round of WER testing. For WER calculations, STSIU surface-water samples were matched to a laboratory dilution water toxicity test based on the hardness concentrations in each water type according to USEPA (1994). Hardness concentrations for all laboratory-water toxicity tests were selected based on the hardness of STSIU samples measured when the water samples arrived at GEI. The intent was to match water hardness between field and laboratory samples as close as possible while meeting WER testing requirements, including equal or lower water hardness in matched laboratory dilution water (unless hardness in site water is less than 50 mg/L as CaCO_3 ; USEPA 1994). Consistent with USEPA guidance, all laboratory dilution-water toxicity tests were conducted at water hardness between 40 and 220 mg/L as CaCO_3 .

2.1 Data Analysis

Acute toxicity of contaminants to aquatic organisms is usually evaluated in terms of the concentration needed to kill or cause adverse effects to 50% of the tested organisms [i.e., median effect concentrations (EC50 values)]. In this WER study, EC50s values were calculated based on total and dissolved copper concentrations using maximum likelihood probit analysis in ToxCalc™ version 5.0 software (Tidepool Scientific Software, McKinleyville, California). One-half the detection limit was used in all samples for which copper concentration was below the method detection limit (MDL). The toxicity results for *D. magna* are reported as EC50 values because immobilization was used as a surrogate for death in those organisms (as discussed in USEPA 2002).



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In accordance with USEPA (1994, 2001) guidance, the WER for each sample was calculated from the EC50 values in STSIU site water and the laboratory water, as follows:

$$\text{WER} = \frac{\text{Site-Water EC50}_{\text{hardness-normalized}}}{\text{Lab-Water EC50}_{\text{hardness-normalized}}} \quad (\text{Eqn. 1})$$

where:

$\text{Site-Water EC50}_{\text{hardness-normalized}}$ = the copper EC50 obtained in STSIU site water, adjusted to a standard hardness using the copper-criteria hardness slope and equation 2 (shown below), and

$\text{Lab-Water EC50}_{\text{hardness-normalized}}$ = the copper EC50 obtained in laboratory water, adjusted to a standard hardness using the copper-criteria hardness slope and equation 2 (shown below).

Normalization of each EC50 value used in a WER calculation is intended to account for the differing hardness concentrations of site and laboratory water and is a requirement specified in each WER guidance document (USEPA 1994, 2001). In this WER study, all EC50 values were normalized to a hardness of 100 mg CaCO₃/L, as follows:

$$\text{EC50}_{\text{hardness-normalized}} = \text{EC50}_{\text{at sample hardness}} \cdot \left(\frac{\text{StdH}}{\text{SampleH}} \right)^{0.9422} \quad (\text{Eqn. 2})$$

where:

$\text{EC50}_{\text{hardness-normalized}}$ = the copper EC50 adjusted to a standard hardness concentration (i.e., the predicted EC50 if the sample hardness had equaled the standard hardness),

Std H = a standard hardness concentration to which all EC50 values are normalized (a hardness of 100 mg/L as CaCO₃ was used to normalize all EC50 values in this study),

Sample H = the hardness of the laboratory water, the site water, or the species mean acute value (SMAV),

0.9422 = the log-log regression slope for the 1984/1985 and 1995 USEPA acute copper criteria, which is also the slope currently used for the copper criteria in the New Mexico Water Quality Standards.

2.2 Statistical Evaluations

The following sections describe statistical evaluations and copper biotic ligand model (BLM) analyses performed on the chemistry and toxicity data presented in ARCADIS (2013a).

All statistical evaluations of the toxicity and chemistry data, including linear correlation and regression analyses, were performed using SigmaPlot™ version 12.1 software (SYSTAT Software, Inc., San Jose, California). A Pearson Correlation analysis was performed on all the chemical and toxicity variables to calculate correlation coefficients (*r*-values) and the level of significance (i.e., *p*-value) between pairs of the variables, to help understand the degree and direction of the linear relationship between pairs of variables (including comparisons of a toxicity endpoint versus a water chemistry parameter, or comparisons of pairs of water chemistry parameters). Results from this correlation analysis were considered when selecting parameters to include in additional regression analyses. For regression analyses, data were log-transformed with the exception of pH data (which already is the negative logarithm of the hydrogen-ion concentration). Toxicity endpoints were then regressed against individual water chemistry parameters (i.e., using univariate linear regression). Based on the above analyses, in conjunction with knowledge of the mechanisms of copper toxicity and bioavailability, step-wise multiple linear regression (MLR) analyses were performed using various combinations of water chemistry parameters to determine the best subset of parameters for predicting the observed toxicity. The best-fit model was based on the coefficient of determination (i.e., R^2) of the regression, the *p*-value, and evaluation of the significance level of each variable's coefficient (for the MLR analyses).

2.3 Statistical Criteria

The *a priori* specified level of significance of $\alpha = 0.05$ was used as a basis for identifying statistically significant relationships. Thus, correlation and regression *p*-values of ≤ 0.05 are considered significant, although *p*-values that approached this specified level of significance were also considered when interpreting results. For the MLR analyses, care was taken to limit co-linearity of water chemistry parameters selected for the toxicity-prediction model, as judged by the variance inflation factor (VIF). Co-linearity between two chemistry parameters was determined to be significant

(and thus might potentially confound results) if the calculated VIF value was ≥ 4 , and only the more significant variable (based on univariate correlation) was potentially used in the model.

2.4 Copper Biotic Ligand Model (BLM) Evaluations

The copper BLM (version 2.2.3; available at http://hydroqual.com/wr_blm.html) was used to predict copper EC50 values for *D. magna*. Measured pH, alkalinity, and concentrations of dissolved organic carbon (DOC), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chloride (Cl⁻), and sulfate (SO₄²⁻) were used as model input parameters for all site-water toxicity tests. In addition, default values for percent humic acids (10%) and sulfide (0.01 μM) were used, consistent with recommendations in the BLM User's Manual (HydroQual 2007).

3. Results

All data analyses described in this report use data presented in the ARCADIS (2013a) tables, but are separate evaluations from the referenced report. Data tables presented in ARCADIS (2013a) are included in **Appendix A** for reference. Additionally:

- A summary of the Pearson Correlation analyses performed between pairs of toxicity endpoints and water chemistry parameters is provided in **Appendix B**.
- **Appendix C** provides the SigmaPlot™ statistical software output for all the univariate (i.e., single-predictor) linear regression analyses performed with pairs of parameters.
- **Appendix D** provides the SigmaPlot™ statistical software output for all the MLR analyses performed with combinations of multiple parameters.
- **Appendix E** provides an evaluation of surface-water chemistry ranges observed in STSIU.
- **Appendix F** presents an evaluation of the protectiveness of the proposed WER model to Chiricahua leopard frog.

3.1 Interim Report Results

Results presented in ARCADIS (2013a) broadly indicate that the current hardness-based copper criteria are overprotective of aquatic life uses in most STSIU surface-water samples tested. This finding is based on comparing copper toxicity endpoints measured in Site-water samples to the same copper toxicity endpoints measured in laboratory dilution-water samples. *D. magna* copper EC50, which is the concentration of copper required to cause adverse effects to 50% of the test organisms, was the

toxicity endpoint used in these studies. WERs were calculated for each sample as the quotient of the site-water EC50 divided by the laboratory-water EC50; WER values greater than 1 indicate copper is less toxic in the Site water than in the laboratory dilution water.

WERs were calculated and presented in ARCADIS (2013a) using several different WER denominators that correspond to the various approaches described in the Interim WER guidance (USEPA 1994) and in the Streamlined Copper WER guidance (USEPA 2001). Based on comments received from NMED SWQB, Chino agreed that the approach described in USEPA (2001) would be used for the WER calculation. In that approach, if the hardness-normalized laboratory-water EC50 is less than the hardness-normalized species mean acute value (SMAV) presented in USEPA (2001) for *D. magna*, the SMAV should be used in the WER denominator. Normalized to a hardness of 100 mg/L as CaCO₃, the *D. magna* SMAV for dissolved copper is 19.31 µg/L.

Table 1 lists the measured WER values reported in ARCADIS (2013a) that were calculated using that SMAV in the denominator. Measured WERs ranged from 0.989 to 14.41, indicating that site-specific copper toxicity was variable when compared across all the surface-water samples. **Table 1** also lists:

- Dissolved copper concentrations measured in WER samples;
- The hardness-based copper criteria maximum concentration (CMC, or acute criteria) calculated from the hardness measured in each sample;
- Compliance ratios calculated by dividing the measured copper concentrations by the hardness-based copper CMC (e.g., dissolved copper / CMC), and
- Compliance ratios calculated by dividing the measured copper concentrations by their respective WER-adjusted copper CMC (e.g., dissolved copper / [CMC x WER]).

Hardness-based copper compliance ratios that are greater than 1 indicate an exceedance of the hardness-based copper CMC. As listed in **Table 1**, dissolved copper concentrations in seven samples exceeded the hardness-based CMC, with compliance ratios in those seven samples ranging from 1.2 to 7.6. However, when the WER determined for each sample is used to adjust the sample's hardness-based CMC, all of the resulting adjusted compliance ratios are less than 1. This approach is consistent with the sample-specific WER approach described in USEPA (1994: pp. 14-15), which can be used to evaluate whether metal concentrations in a sample are acceptable after accounting for the effect of site-specific water chemistry (i.e., by using the measured WER to adjust the CMC). As stated in USEPA (1994), the metal concentration of a sample is acceptable when the adjusted compliance ratio is less than 1. Based on this analysis, copper was within acceptable compliance ranges for all

test samples, after applying the sample WER to account for the protective effects of site-specific water chemistry on the aquatic toxicity of copper. Broadly, this indicates copper toxicity in Site waters is less than predicted by the current hardness-based copper criteria.

One of the objectives of the WER study design, as described in ARCADIS (2011, 2013a), was to include a chemically and spatially diverse set of sample locations. The map presented in **Figure 1** shows that WER samples were collected in eight different sub-watersheds; these samples were collected during two separate sampling rounds in 2011. The variability observed in the site-specific toxicity of copper is expected to be related to the variability of water chemistry, as described in ARCADIS (2013a). In accordance with USEPA (1994), an assumption worth testing is whether the WER correlates to water quality characteristics. This assumption is statistically evaluated in Section 3.2.

3.2 Toxicity and Water Chemistry Correlations

Correlation analyses were performed using the co-located copper toxicity and water chemistry values to determine chemical parameters that were statistically associated with the measured toxicity values. Results from the Pearson Correlation analysis performed on chemistry and toxicity data are summarized in **Appendix B**. These correlation results provide a useful basis to identify water chemistry parameters that are statistically associated with copper toxicity and, therefore, parameters that might require further evaluation when considering site-specific water chemistry effects on copper toxicity. Results from the Pearson Correlation analysis are expressed as the significance level (the *p*-value) and correlation coefficient (the *r*-value) associated with comparisons between two variables.

3.2.1 Influence of Inorganic Water Chemistry Parameters on Observed Copper Toxicity

A greater than 12-fold difference in *D. magna* dissolved copper EC50 values was measured in Site-water samples, ranging from 14.7 µg/L in sample WER-1-12 to more than 184.7 µg/L in sample WER-2-9. An important observation is that hardness concentrations in these low- and high-WER samples were almost equal (e.g., hardness concentrations of 76 and 82 mg CaCO₃/L in samples WER-1-12 and WER-2-9, respectively), indicating that water chemistry parameters other than hardness can have a significant effect on site-specific copper toxicity. This has important site-specific implications because the current New Mexico numeric water quality criteria for copper are based exclusively on sample-specific hardness concentrations. The linear regression presented in **Figure 2** further illustrates the lack of relationship between hardness and copper toxicity in STSIU samples. Specifically, the coefficient of determination (R^2) for the hardness versus EC50 regression is 0.10, which implies that

hardness accounts for only 10% of the variability associated with copper toxicity in these Site waters. As listed in **Figure 2**, the level of significance (i.e., the *p*-value) for the regression coefficient is 0.211, which is greater than the specified α level of 0.05, indicating that hardness is not a statistically significant predictor of copper toxicity in the tested site waters.

Other non-hardness water chemistry parameters are expected to have equal or greater influence on copper bioavailability and toxicity compared to hardness. One such parameter is alkalinity, which is a measure of the acid-neutralizing capacity of water. Alkalinity in most natural fresh waters is due to the presence of carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and hydroxyl (OH^-) anions. In some surface waters, other important non-carbonate contributors to alkalinity include organic ligands and phosphate, ammonium, silicate, sulfide, borate, and arsenate ions (Hem 1985). Alkalinity is generally recognized as influencing copper bioavailability and toxicity in aquatic systems through the formation of less toxic copper-base complexes (Wurts and Perschbacher 1994). Empirical toxicity results reported by others demonstrated that alkalinity generally decreases copper toxicity (as evidenced by increasing copper toxicity endpoints determined at increasing alkalinity concentrations; Meyer et al. 2007). Results from the current study are consistent with this general trend. As an example, **Figure 3** shows that *D. magna* EC50 values were positively correlated with alkalinity having a regression *p*-value of 0.004, indicating a statistically significant relationship between alkalinity and the measured *D. magna* EC50 value ($R^2 = 0.43$).

In most waters, alkalinity and hardness concentrations are similar because the anions of alkalinity (e.g., HCO_3^- and CO_3^{2-}) and the cations of hardness (e.g., Ca^{2+} and Mg^{2+}) are derived from the same carbonate minerals (Meyer et al. 2007). Any sample hardness greater than the corresponding sample alkalinity represents non-carbonate hardness (e.g., CaSO_4 , MgCl_2). In contrast, in waters containing greater alkalinity than hardness, potassium and sodium carbonates/bicarbonates are expected to be a major source of the alkalinity. Although hardness and alkalinity concentrations in the Site-water toxicity samples were well-correlated (**Figure 4**; $R^2=0.68$), relative differences were observed between hardness and alkalinity proportions across all tested waters, which can be an important factor to consider when evaluating toxicity variability, as described below.

That copper toxicity endpoints were significantly correlated with alkalinity, but not hardness, indicates alkalinity might be a better predictor of site-specific copper toxicity than hardness. However, evaluating the relationship between copper toxicity and the relative difference between hardness and alkalinity of a sample is informative to the mechanisms of copper bioavailability and toxicity. A potential metric for this evaluation is the hardness-to-alkalinity ratio (H/A), which can be interpreted as a measure of the alkalinity deficiency of a sample (because alkalinity is typically equal to or less than the

hardness of STSIU waters). As shown in **Figure 5**, copper toxicity in Site water tends to increase (i.e., lower EC50 values) when the hardness concentration is increasingly greater than the alkalinity concentration (i.e., at greater H/A values). In contrast, Site-specific copper toxicity decreases as the hardness-to-alkalinity ratio decreases. Using the hardness-to-alkalinity ratio as a predictor variable for site-specific copper toxicity provides a more statistically significant relationship (i.e., regression coefficient p -value < 0.001 ; $R^2 = 0.54$) compared to regressing the toxicity endpoint against hardness or alkalinity separately. Although the concentration difference between hardness and alkalinity might logically have also been used as a predictor of copper toxicity, it was not as strong a predictor as the hardness-to-alkalinity ratio.

Another non-hardness chemical parameter determined to be significantly correlated to site-specific copper toxicity is total dissolved solids (TDS), which refers to the amount of all inorganic and organic substances in a water sample that passes through a 0.45- μm filter. TDS measurements are not ion-specific (i.e., they do not quantify the mass concentration of a particular ion), but describe the overall mass of all dissolved inorganic and organic constituents. TDS is often correlated with electrical conductivity and the ionic strength of a sample, which have been previously shown to influence the toxicity of copper to aquatic organisms. Major ions typically responsible for the TDS content of a sample include calcium, magnesium, sodium, potassium, bicarbonate, phosphates, nitrates, chloride and sulfate. As indicated in **Figure 6**, copper toxicity generally decreased as TDS concentration increased (p -value = 0.04; $R^2 = 0.25$).

3.2.2 Influence of Organic Carbon on Observed Copper Toxicity

Organic carbon is well-known to have an important effect on copper bioavailability and toxicity to aquatic organisms (EPA 2007, Meyer et al. 2007). The Interim Report described how both total organic carbon (TOC) and DOC varied substantially in water samples collected throughout the STSIU drainages. This organic carbon variability explains a substantial portion of the variability of toxicity measured in the STSIU surface-water samples. As shown in **Figures 7 and 8**, both TOC and DOC were well-correlated with site-specific copper toxicity, with toxicity decreasing (i.e., EC50 values increasing) as TOC and DOC concentrations increased. Based on all statistical analyses conducted and presented herein, organic carbon (either as DOC or TOC) was the single parameter most statistically correlated to site-specific copper toxicity (TOC: $R^2 = 0.62$, p -value < 0.001 ; DOC: $R^2 = 0.75$, p -value < 0.001). Mechanistically, organic carbon decreases the free-ion (i.e., Cu^{2+}) concentrations through the formation of copper-organic carbon complexes, thereby decreasing the bioavailability of copper to aquatic organisms and thus decreasing its toxicity (Meyer et al. 2007).

In addition to the statistical relationships described above and the mechanistic importance of organic carbon to copper bioavailability, the relationship between organic carbon and copper toxicity has important Site-specific implications because of the variability and relatively high concentrations of organic carbon measured in STSIU surface waters (**Table 2**). Dissolved organic matter (DOM) is a ubiquitous component of natural surface and ground waters, and is chemically composed of a variety of carbon-based constituents including a small proportion of identifiable, low-molecular weight compounds such as carbohydrates and amino acids, and a larger proportion of complex, higher-molecular weight compounds collectively termed humic substances. DOM is operationally defined as any organic compound passing through a 0.45- μm filter (Evans et al. 2005).

The DOC component of DOM is conventionally measured as a surrogate to DOM concentrations, and DOC is assumed to constitute approximately $\frac{1}{2}$ the mass of the DOM. Concentrations of DOC in natural waters vary widely, from less than 1 to greater than 50 mg/L (Thurman 1985). Concentrations of DOC in natural waters typically vary depending on watershed hydrologic conditions, geology, soil types, land-use, climate, and aquatic life. Generally, the lowest values are observed in the oceans, groundwater, and oligotrophic lakes and rivers draining bare rock or thin, organic-poor soils (Evans et al. 2005). Concentrations are highest in organic soil porewater, and fresh water draining wetlands and peat lands, especially where runoff is low and hydrologic residence time is high (Evans et al. 2005). In ephemeral stream systems typical of the arid southwest, the limited hydrologic flushing of adjacent uplands in conjunction with longer hydrologic residence times can contribute to moderately high aqueous organic carbon concentrations. In a study that characterized organic carbon in arid stream systems in the southwest, Westeroff and Anning (2000) reported that organic carbon concentrations were greater in ephemeral streams compared to nearby perennial stream systems. In these ephemeral systems, algae growth in the channel can represent a significant source of autochthonous (i.e., internally generated) organic matter and can potentially be a more important source of organic carbon than terrestrial plants due to the relatively sparse upland plant cover.

3.2.3 Consideration of Other Water Chemistry Parameters

Other chemical parameters such as total suspended solids (TSS), pH, and other ions can potentially affect copper toxicity to aquatic organisms. Presented as Pearson Correlation results (i.e., r -values and p -values), **Appendix B** provides a summary of relationships observed between measured copper EC50s and these chemical parameters (in addition to relationships between pairs of chemical parameters).

Although pH can mechanistically influence copper bioavailability and toxicity to aquatic organisms (Meyer et al. 2007), a significant relationship was not observed in the



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current study between pH and copper EC50 values (r -value = -0.314; p -value = 0.220; **Appendix C** and **Figure 9**). Additionally, pH was not significantly associated with other inorganic parameters such as hardness, alkalinity, or TDS. However, a significant relationship was observed between pH and DOC (r -value = -0.488; p -value = 0.047) and the relationship between pH and TOC approached the specified level of significance of $\alpha = 0.05$ (r -value = -0.398; p -value = 0.114). Greater DOC and TOC values were associated with lower pH values, perhaps because high concentrations of humic/fulvic acids (which can dominate DOC and TOC concentrations) tend to slightly acidify natural waters.

TSS was not significantly associated with copper EC50 values (r -value = 0.266; p -value = 0.301). The lack of relationship between copper EC50 values and TSS is not surprising because the current EC50 values are based on the dissolved fraction of copper to be consistent with the current aquatic life standard for copper in New Mexico. Accordingly, the amount of solids dissolved in a water sample (i.e., TDS concentration) is likely to be more important than TSS when considering mechanisms of dissolved copper bioavailability and toxicity. This is supported by the significant relationship observed between TDS and copper EC50 values described in Section 3.2.1. In contrast, TSS probably would be an important determinant of the bioavailability and toxicity of total recoverable copper in STSIU waters; however, total recoverable copper is not of regulatory concern in this situation.

Other ions such as potassium, calcium, magnesium, sodium, and sulfate were either significantly associated with copper EC50 values (i.e., p -values < 0.05) or approached the specified level of significance of $\alpha = 0.05$ (**Appendix C**). However, these ions are explicitly accounted for by other inorganic parameters described in Section 3.2.1, including hardness, alkalinity and TDS. As a result, these ions are highly correlated to hardness, alkalinity and TDS (**Appendix B**) and thus should not be included in a statistical model of copper toxicity, because their inclusion would cause concern about co-linearity with other predictor variables.

3.2.4 Influence of Multiple Water Chemistry Parameters on Observed Copper Toxicity

The effect of multiple water chemistry parameters on the aquatic toxicity of metals is widely documented in the scientific literature (e.g., see review in Meyer et al. 2007), and reflected in USEPA options for site-specific criteria derivations (i.e., WER Procedure and the USEPA Copper BLM). An important finding from the above analyses is that multiple water chemistry parameters significantly influenced copper toxicity, and the relationship between these parameters is consistent with mechanisms of copper toxicity and consistent with relationships previously reported in the scientific literature. A series of MLR analyses were therefore performed in an effort to more fully examine effects of varying Site chemistry on dissolved copper toxicity.

Chemical parameters were evaluated in MLR analyses based on the correlation results (**Appendix B**), linear regression analyses (as described in the above Section and presented in **Appendix C**), and consideration of mechanisms of copper bioavailability and toxicity. **Table 3** lists the statistical summaries of the various MLR models evaluated (see **Appendix D** for complete statistical summaries of all evaluated MLR models).

The MLR models were evaluated on a statistical basis for predictive capabilities and by considering the relationship between water chemistry parameters and copper toxicity. Specific statistical criteria and relationships considered include:

- *Overall statistical fit:* Multiple-regression coefficients (i.e., R^2 and adjusted R^2) were used to evaluate the strength of the predictive relationship between sets of water chemistry parameters and copper toxicity. The statistical significance of the multiple-regression coefficient was also considered (i.e., by examining the overall regression p-value), although most MLR models considered were highly significant (i.e., $p < 0.001$). Because different numbers of predictor variables (i.e., water chemistry parameters) were evaluated across MLR models, the adjusted R^2 value was considered the most appropriate basis to compare the predictive strength among models. The adjusted R^2 takes into account the sample size and the number of predictor variables (and uses variances instead of the variations), which provides a more relevant diagnostic measure in multiple-regression analysis, especially when additional predictor variables are added to the model. An important point is that R^2 values can only increase or stay the same when additional predictor variables are added to a MLR model, regardless of whether the added variables is a significant predictor. In contrast, the adjusted R^2 value is sensitive to the number of predictor values and can decrease as additional predictor variables are added.
- *Strength of relationship between individual predictor variables and copper toxicity:* The strength of relationships between individual water chemistry parameters and copper toxicity was evaluated by the variable's coefficient p-value (or level of statistical significance). The specified level of significance of $\alpha = 0.05$ was used as a general basis for evaluating the significance of a single parameter, or whether a single parameter improved the statistical fit of the MLR model.
- *Multicollinearity:* The degree of correlation between predictor variables (referred to as multicollinearity) was examined when evaluating MLR models. When any one predictor variable can be predicted to a high degree from one or more other predictor variables (i.e., high correlation between predictor variables), MLR model estimates are considered unstable. Therefore, only the most predictive variable in a set of highly correlated variables should be entered into an MLR model.

- *Linkage between water chemistry and copper toxicity:* Parameters were selected for MLR evaluation based on their relationship to copper bioavailability and toxicity. Care was taken to select key, individual parameters that were previously identified as being significantly correlated to measured copper toxicity (based on results presented in Section 3).

Based on these criteria, several potential predictive MLR models were identified in the step-wise multiple linear regression analysis (Table 3). Key predictor variables included: TOC, DOC, alkalinity, and TDS. Of the models and parameters evaluated, one of the the best-fit MLR models (based on the R^2 value, adjusted R^2 value, and coefficient p -values) combined four variables previously shown to affect copper toxicity – TOC, hardness, alkalinity, and TDS. This model had high predictive power ($R^2 = 0.869$, adjusted $R^2 = 0.838$, and regression p -value < 0.001), and each input parameter significantly contributed to the statistical fit of the model (i.e., regression coefficient p -values for each parameters was less than 0.05; Model 1 in Table 3). Note that replacing TOC with DOC in this model also yields a highly predictive model (adjusted $R^2 = 0.838$; Model 2 in Table 3). In both of these models, hardness and alkalinity were combined into a hardness/alkalinity ratio.

A potential limitation of using the hardness/alkalinity ratio as a predictive measure of toxicity is that alkalinity concentrations are not explicitly accounted for. Because the ratio of hardness/alkalinity is a proportional measure of the two parameters, it might not directly reflect the range of protective effects across low and high carbonate/bi-carbonate concentrations. For example, a similar hardness/alkalinity ratio is possible at low alkalinity concentrations and at higher alkalinity concentrations, but the protectiveness effects would be expected to differ (based on the relationship between alkalinity and copper toxicity discussed in Section 3). Alkalinity by itself (i.e., not as the hardness/alkalinity ratio) was therefore evaluated as an input parameter to MLR models.

Replacing the hardness/alkalinity ratio with alkalinity (but keeping TOC and TDS) provides a model with an adjusted R^2 value of 0.766 (Model 15 in Table 3). However, the p -value for TDS in this regression model is 0.839 indicating that TDS is not a significant predictor of toxicity when combined with TOC and alkalinity. A similar result is obtained by using DOC, alkalinity and TDS as predictor variables (i.e., adjusted $R^2 = 0.829$, but TDS not a significant parameter [p -value = 0.448]). These results suggest that when alkalinity is used instead of the hardness/alkalinity ratio as a model parameter, including TDS does not improve the statistical fit of the model. Additional regression analyses were therefore performed using either TOC or DOC and alkalinity as parameters and excluding TDS (Table 3).

The combination of DOC and alkalinity yields a MLR model with an adjusted R^2 value of 0.833 (and co-efficient p -values of less than 0.05 for DOC and alkalinity; Model 18 in

Table 3), which is almost identical to the variance accounted for by the MLR model evaluated above that incorporated TOC (or DOC), hardness/alkalinity, and TDS. As inferred from an adjusted R^2 value of 0.833, the combination of DOC and alkalinity explains 83 percent of the measured variability in copper toxicity (compared to an adjusted R^2 value of 0.838 using DOC (or TOC), hardness/alkalinity, and TDS). In multiple-regression analysis, it is desirable to limit the number of predictor variables while maximizing the predictive relationship, particularly with smaller datasets, thus making Model 18 (DOC and alkalinity) preferable over Model 1 (DOC or TOC plus hardness/alkalinity and TDS) in Table 3. Additionally, because alkalinity is used as predictor of copper toxicity in the BLM and the hardness/alkalinity ratio is not, Model 18 (DOC and alkalinity) is preferable over Model 1 (DOC or TOC plus hardness/alkalinity and TDS) from a mechanistic perspective.

To further validate the accuracy of these MLR models and to understand any potential bias in model-predicted values, a residual-based analysis was performed. Figure 10 graphically depicts the accuracy of model-predicted toxicity values when compared to measured toxicity values. In this approach, copper toxicity is predicted by applying the MLR model equation to the water chemistry values measured in the toxicity test sample to derive a model-predicted toxicity value. In effect, this residual-based analysis quantitatively compares measured toxicity values to model-predicted toxicity values which are derived by applying the MLR equation to measured water chemistry. Figure 10 shows that MLR-predicted copper toxicity values from each model were strongly correlated with measured toxicity. The solid diagonal line on Figure 10 represents perfect agreement between the observed and predicted values (i.e., predicted values equal observed values), while the dotted lines represent two-fold deviations of the observed toxicity from the predicted toxicity. A two-fold variation in a measured toxicity endpoint is a commonly-used range to represent the natural variability considered to be inherent in toxicity testing procedures (Di Torro et al. 2001, Esbaugh et al. 2011). Importantly, Figure 10 shows that the model-predicted copper toxicity values from each model are highly accurate (relative to the observed values), and a bias is not evident in either model. That is, neither model appears to systematically over- or under-predict toxicity when evaluated across the range of observed toxicity values. Predicted values are within two-fold of the observed values, which provides a strong indication of accuracy for each MLR model.

3.2.5 CopperBLMComparisons

The copper BLM offers a computational tool to evaluate the protective impact of water chemistry on copper toxicity by systematically combining the complexation and competitive properties of water chemistry parameters (Di Torro et al. 2001, Paquin et al.



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2002). Input parameters for the BLM calculations are temperature, pH, alkalinity, and concentrations of Ca^{2+} , Mg^{2+} , Na^+ , K^+ , Cl^- , SO_4^{2-} , and DOC. Although the current USEPA-promulgated water quality criteria (WQC) for copper are based on the BLM (USEPA 2007), to date no state has adopted the Cu-BLM as a primary basis for a state copper criterion. Recent studies have indicated disparities in BLM-predicted and empirical toxicity endpoints, suggesting variable BLM performance in different water types relative to the waters used to develop the BLM. One potential explanation for this discrepancy is that the BLM is based on one possible composition of organic matter (i.e., assumed 10 percent fulvic acid), which may differ chemically from the types of DOM in Site waters. Another potential explanation is that the sensitivity of the organisms used in those toxicity tests differed from the sensitivity of the organisms used in the toxicity tests to which the BLM is calibrated. However, in this study the BLM performed reasonably well in predicting toxicity in Site waters. **Figure 11** shows that the BLM-predicted copper EC50s were well-correlated to the observed copper EC50s ($R^2 = 0.66$; p -value < 0.001), but were biased high, indicating the BLM under-predicts copper toxicity (i.e., predicts greater EC50s) when compared to observed values (i.e., measured EC50 values). The majority of BLM-predicted EC50 values (11 out of 17) were more than two-fold greater than actual observed copper EC50 values (**Figure 11**). However, as indicated by the correlation statistics, the BLM predictions generally agreed with observed values, with the lowest predicted EC50 values corresponding to the lowest observed EC50 values and the highest BLM-predicted EC50 values corresponding to the highest observed EC50 values (i.e., a positive relationship between BLM-predicted and observed EC50s). This finding is consistent with the above observations concerning the effects of variable water chemistry on site-specific toxicity, with the range of BLM predictions corresponding overall to the range of water chemistry.

Comparing the MLR model predictions and the BLM predictions to the observed toxicity values (**Figures 10 and 11**, respectively) indicates the MLR model provides a more accurate prediction of site-specific copper toxicity than the BLM. This finding is based on the regression statistics and by considering whether either model over- or under-predicts toxicity over the relatively wide range of water chemistry and observed toxicity values. Given the above trends, it follows that BLM-predicted EC50s were also well-correlated with the EC50s obtained with the MLR model. As shown on **Figure 12**, the BLM EC50s were strongly correlated with the MLR model EC50s, but were biased high (i.e., BLM-predicted EC50s were consistently greater than the MLR model-predicted EC50s). Although BLM-predicted EC50s were consistently greater than MLR model-predicted EC50s, the strong correlation between the two models further highlights the effect of water chemistry on site-specific toxicity and further corroborates the MLR model structure and performance.



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To provide additional context to the BLM, a brief description of the various BLM applications follows. The BLM offers separate applications to evaluate copper toxicity (i.e., the toxicity-prediction mode option) and copper speciation (i.e., the chemical speciation mode option). When run in speciation mode, the BLM predicts the chemical speciation of dissolved copper including complexation with inorganic and organic ligands, and the biotic ligand. When run in toxicity-prediction mode, the BLM predicts the median lethal or effect concentration (i.e., LC50 or EC50) based on the user-selected organism and the site-specific water chemistry parameters. In addition to these applications, the BLM can be used to predict site-specific copper water quality criteria by selecting the *Cu WQC Calculation* option.

The BLM-based evaluations and figures presented herein and discussed during the June 10, 2013 meeting were performed by using the BLM in toxicity prediction mode (i.e., comparing the BLM-predicted EC50s to the measured EC50s). These BLM predictions were made by using the BLM "out-of-the-box", which refers to running the BLM with the default sensitivity parameters. As discussed during that meeting, the BLM can be adjusted to potentially improve these toxicity predictions by modifying the median lethal accumulation concentration (LA50) in the program file for the user-selected organism. The LA50 value is the concentration of copper accumulated on the biotic ligand that results in 50% mortality in a toxicological exposure (i.e., the amount of metal accumulated on the biotic ligand that results in the water column EC50).

As shown on Figure 11, the BLM systematically over-predicted the EC50 values when compared to the measured EC50 values. Therefore, the default LA50 value listed in the program file could be decreased to predict lower EC50 values, which would result in better agreement between the BLM-predicted and measured EC50 values. However, this adjustment would only affect the BLM's toxicity predictions (i.e., predicted EC50 values), and would not impact the predicted site-specific copper criteria derived from the *Cu WQC Calculation* option. This option is EPA's recommended approach for using the BLM to derive site-specific criteria. The program files used to make the BLM's Cu WQC predictions are not publicly available, and ARCADIS does not currently have access to these. During the June 10, 2013 meeting, ARCADIS discussed the possibility of obtaining these parameterization files from the developers of the BLM (Hydroqual) to perform such modifications. Although this approach might be feasible, these files are not accessible to the public or scientific community, and could therefore limit the general acceptance of this approach since criteria predictions would not be reproducible by others. Additionally, modifying the parameterization of the BLM's Cu WQC calculations could be inconsistent with EPA's current BLM-based criteria approach, and would thus need to be fully evaluated in conjunction with EPA and BLM developers.



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With this background, Chino does not recommend using a modified BLM (or the BLM "out of the box") to derive site-specific copper criteria for STSIU surface waters. The proposed regression-based approach, which has been developed from empirical toxicity tests conducted in site water, provides a more accurate and technically-defensible approach for deriving site-specific copper criteria *for the STSIU surface waters* (i.e., the proposed approach is highly specific to STSIU surface waters) and is consistent with the approach adopted by Esbaugh et al. (2011). Based on the evaluations presented in this report and discussed during the 6/10/13 meeting, adjusting the BLM to systematically change the predictions is not expected to provide greater predictability compared to the regression model approach.

4. Discussion

4.1 Technical Basis of a WER Model

Section 3.1 describes the USEPA (1994) sample-specific WER approach where the WER value determined in a tested sample is used to adjust the hardness-based copper criteria to evaluate whether copper concentrations are acceptable when the effects of water chemistry are considered. This analysis indicated copper concentrations were within acceptable ranges (when applied according to USEPA [1994]); **Table 1**). Although this approach is informative to understanding copper compliance for a sample, it would be cost-prohibitive and logistically impracticable to perform WER testing to evaluate compliance for all surface waters within the expansive and somewhat remote study area (recognizing that the copper in STSIU waters originates from non-point sources). Therefore, this study evaluated an alternative approach based on statistical relationships between these empirical toxicity results and Site-water chemistry.

One of the primary findings from the Interim Report (ARCADIS 2013a) was that the measured WERs were variable, reflecting the influence of variable Site-specific water chemistries on copper toxicity. This finding highlighted the need to further understand the influence of site-specific water chemistry on observed copper toxicity. Statistical evaluations (presented in Section 3) were thus performed to better understand the statistical association between measured toxicity and chemistry parameters. Based on the best-fit MLR model, the combination of DOC and alkalinity explained 83% of the variability in the observed copper toxicity values. This relationship provides a highly predictive tool for estimating site-specific copper toxicity based on using measured water chemistry values as input parameters to a predictive Site-specific copper model.

In addition to providing a statistically robust option to derive Site-specific copper criteria, a Site-specific MLR model approach can address the challenges associated with the Site conditions described previously. Because the model was developed from



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toxicity tests conducted in actual site water, which covered a relatively wide range of values of a variety of chemical parameters, the model is expected to perform very well in water chemistries that are typical of surface water at the Site (i.e., the model is highly specific to Site-water chemistries).

The Site-specific MLR approach can reduce uncertainty about the over-protectiveness or under-protectiveness of the current hardness-based criteria, or uncertainty associated with application of other site-specific criteria options such as the BLM or a traditional WER approach.

- First, compared to the current hardness-based copper criteria, the MLR-model approach considers the effects of multiple water chemistry parameters on Site-specific copper toxicity. This provides a more accurate estimate of copper toxicity across Site waters because other toxicity-modifying parameters are accounted for. Although hardness was not determined as a strong predictor variable in the best-fit MLR model, the proposed WER model approach still accounts for hardness by normalizing the site and laboratory water to the same hardness.
- Second, compared to the BLM, the MLR-model approach predicts toxicity based on the relationship between measured Site toxicity and chemistry values. Because the BLM approach does not include empirical toxicity tests to confirm its computational-based predictions, the MLR-model approach can reduce uncertainty associated with default BLM assumptions and/or take into account how other water chemistry parameters that are not incorporated into the BLM affect toxicity characteristics of a water (such as other co-occurring metals and type or quality of organic matter).
- Third, compared to the traditional WER approach in which a single or set of static site-specific criteria are applied to a water body, the MLR-model offers a way to evaluate copper compliance on a sample-specific basis, similar to the BLM and hardness-based options.

Another important consideration when evaluating the technical basis of this MLR-model approach is that regression analyses are commonly used to derive WQC. For example, the current hardness-based WQC for a number of divalent metals (including copper) are based on regressions between laboratory-water toxicity endpoints and water hardness. The current WQC for these select divalent metals are thus expressed as univariate linear regression equations, using hardness as the single predictor variable to determine the numeric WQC value. Further, the current USEPA ammonia WQC are based on a multivariate regression model that uses temperature and pH as input variables. With this background, the MLR-model approach described in this report is conceptually consistent to current approaches used to calculate WQC values.



Applying this type of MLR-model approach to the WER procedure framework should therefore provide a robust and technically-defensible basis to develop and apply SSC.

4.2 WER Model Implementation

The proposed approach to applying the MLR-model to derive site-specific copper criteria that can be applied to STSIU surface waters is described below:

1. Input a sample's measured water chemistry values into the MLR-model equation to calculate a predicted Site copper EC50 value;
2. Normalize the predicted EC50 value to a standard hardness (e.g., 100 mg/L as CaCO₃), using Equation 2 presented in Section 2.1. This value becomes the numerator to the WER equation;
3. Divide the normalized predicted Site EC50 value by the hardness-normalized *D. magna* SMAV for copper (normalized to the same hardness used in Step 2) to calculate a sample WER.
4. Multiply the sample WER by the hardness-based copper standard (calculated at the hardness of the water sample) to derive a site-specific standard for the sample.

Table 4 provides a step-by-step example of how to apply this approach to derive a site-specific standard for a sample (using measured water chemistry from sample WER-1-1 as the example). The proposed regression-model approach is sample-specific, meaning a site-specific standard is derived for each sample based on its water chemistry. Operationally, the approach is consistent with the current hardness-based standards approach whereby the copper standard for a single sample is determined based on its hardness concentration. Therefore, Chino envisions that compliance evaluations (i.e., determining whether measured copper concentrations in a sample are acceptable) that use SSC developed with the proposed regression-model approach will be the same as compliance evaluations that use criteria developed with the current hardness-based approach.

Elements of the WER procedure are still applied in this approach to account for copper toxicity differences between site and laboratory waters, but the numerator of the WER (i.e., the Site-water toxicity endpoint) is modeled based on the statistical relationship

between measured toxicity and measured water chemistry. By applying the WER procedure framework to this approach, hardness is accounted for by normalizing the site and laboratory toxicity endpoints to the same hardness and by using the WER to adjust the sample's hardness-based standard. Thus, criteria-adjustments made using the proposed model are still hardness-specific, but they also take into account other toxicity-modifying water chemistry parameters.

4.2.1 Model Application to Acute and Chronic Criteria

As described in ARCADIS (2013a), surface-water samples used in the WER toxicity tests were collected from pools that were found in predominately bedrock sections of drainage channels, ranging in size from small and shallow to large and deep pools. Although some of these pools were more perennial in nature (such as some pools in Rustler Canyon), many were temporary pools (i.e., intermittent or ephemeral) that were formed from recent precipitation.

Site-specific copper criteria derived from the proposed approach are applicable to acute or chronic criteria. In accord with USEPA WER guidance (USEPA 1994 and 2001), a WER derived from acute toxicity tests is applied to both acute and chronic criteria. As stated in USEPA (2001), because the involvement of strong binding agents causes the WER to increase as the effect concentration decreases, the WER derived from acute tests is expected to be protective of chronic effects. Thus, the WER derived from the proposed approach can be applied to the existing Criteria Maximum Concentrations (CMC [acute criteria]) or the Criterion Continuous Concentration (CCC [chronic criteria]) to derive a Site-specific acute or chronic criterion.

4.2.2 Margin of Safety Applications

As described in USEPA (1994), ambient water quality criteria are typically overprotective of aquatic life uses because they are derived to be environmentally conservative in most bodies of water. The WER procedure is a USEPA-developed method intended to decrease or eliminate overprotection in waters that contain elevated concentrations of water chemistry parameters that protect against metal toxicity. In the traditional WER procedure (where multiple WERs are determined and the geometric mean WER is typically used to derive site-specific criteria for one or more bodies of water), variation in WERs and water chemistry can be a concern when considering the appropriate level of protection and conservatism. Spatial variation among WERs within a body of water is not a concern in the USEPA (1994) sample-specific approach (described in Section 3.1) because compliance is evaluated based on the chemistry, toxicity, and criteria of a single effluent and its receiving water. The proposed application of the MLR-model described herein is similar to this approach in that criteria and compliance is computed on a sample-by-sample basis.

A margin of safety in the proposed MLR-model approach is important to ensure that a sufficient level of protection to resident aquatic life is afforded by a derived site-specific standard. The proposed model approach has several features that do provide a margin of safety to ensure the approach is applied in an environmentally conservative way.

4.2.2.1 WER Denominator

Based on toxicity results measured in this study, use of the SMAV as the denominator to measured Site toxicity values provides a conservative WER value because of differences in organism sensitivity represented by each toxicity endpoint. The Criteria Adjustment Interim Report (ARCADIS 2013a) and response to comments (ARCADIS 2013b) evaluated possible WER denominators, including (1) matched-laboratory water tests conducted side-by-side with Site water tests; (2) the geometric mean of these laboratory tests; (3) the re-calculated SMAV (recalculated by excluding nominal toxicity endpoints from the USEPA [2001] SMAV value); and (4) the SMAV presented in USEPA (2001), which is the WER denominator proposed in this approach). Of the potential denominators, the USEPA (2001) SMAV is the largest value, which results in the smallest WER when applied to Site toxicity values. As a result, this yields a conservative WER and thus provides a margin of safety when used to derive a Site-specific standard. The basis of this conclusion is described in more detail below (also refer to ARCADIS 2013a for further discussion of laboratory-water toxicity endpoints).

Toxicity endpoints measured in the laboratory water toxicity tests were always less than the *D. magna* SMAV presented in USEPA (2001). All aspects of the laboratory water toxicity tests (test design, water chemistry, and toxicity results) were evaluated to ensure results were appropriate and acceptable according to guidance provided in USEPA (1994). ARCADIS (2013a) showed that the laboratory dilution water chemistry was acceptable and representative of standard reconstituted water used to derive national criteria (i.e., low TOC and TSS, appropriate hardness concentrations, and appropriate alkalinity and pH for the hardness ranges tested). Additionally, copper toxicity endpoints were within the range reported by others (including the copper toxicity values for *D. magna* used to derive the current copper standard and *D. magna* toxicity values used in the USEPA [2001] SMAV calculation).

After validating all aspects of laboratory dilution water tests, the copper toxicity differences measured between Site and laboratory waters can be assumed to represent the mitigating properties of site-specific water chemistry. Applying the SMAV to the WER denominator can therefore provide a margin of safety because the sensitivity of the numerator (i.e., site-water toxicity endpoint) is not adjusted to correspond to the sensitivity of the denominator (i.e., organisms represented by the SMAV). Therefore, this ensures a conservative WER value is derived.

4.2.2.2 Chemistry Variability and Model Limits

A major advantage of the WER model approach is that it accounts for water chemistry variability when deriving a site-specific standard because the numeric value of the site-specific standard is a function of the water chemistry for a sample. This approach is consistent with the current hardness-based approach whereby a copper standard is derived based on the hardness concentration of a sample. As with the hardness-based approach, it is important to apply the WER model to water chemistries within the range of those used to develop the model. For example, the current hardness-based approach specifies upper and lower hardness limits to the criteria equation: 25 mg/L and 400 mg/L as CaCO₃. These limits approximate the range of hardness concentrations from toxicity studies used to develop the hardness-based criteria; application of the equation to hardness concentrations outside of this range is uncertain because the linear relationship between toxicity and hardness might not apply. Therefore, a hardness of 25 mg/L CaCO₃ is used to calculate criteria in samples with hardness less than 25 mg/L and a hardness of 400 mg/L CaCO₃ is used to calculate criteria in samples with hardness greater than 400 mg/L. As described below, this framework can also be applied to the WER model approach to ensure criteria adjustments are made in an environmentally conservative way.

Site-specific copper toxicity was measured over a relatively wide range of water chemistries, particularly dissolved organic carbon and alkalinity (the two predictor variables in the proposed WER model). The upper range of DOC and alkalinity concentrations used to develop the WER model will be used as the upper limits when applying the equation to a sample's water chemistry to derive SSC. Based on the Site toxicity data, these ranges are:

- Dissolved Organic Carbon range: 1.2 mg/L - 15.7 mg/L. In samples with DOC concentrations greater than 16 mg/L, a value of 16 will be used in the WER model equation.
- Alkalinity range: 27 mg/L – 250 mg/L. In samples with alkalinity concentrations greater than 250, a value of 250 will be used in the WER model equation.

Applying these limits to samples containing DOC and/or alkalinity concentrations greater than this range provides a margin of safety because more protection against copper toxicity is expected at concentrations greater than those tested and used to develop the model. In this way, the model can be applied in an environmentally conservative way when addressing potential uncertainty associated with applying the model to DOC and/or alkalinity concentrations greater than the model's range.

For samples containing DOC and/or alkalinity concentrations less than the range used to develop the WER model (i.e., DOC = 1.2 mg/L; alkalinity = 27 mg/L), Chino does not



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propose to apply the lower limits of the model when deriving a SSC. Although a lower limit is applied in the current hardness-based approach, less protection against copper toxicity is expected at lower DOC and alkalinity concentrations. Therefore, in samples in which alkalinity or DOC is less than the model range, it would not be conservative to apply the lower limits of the model range to derive a SSC. Figure 13 graphically depicts example SSC values calculated using the proposed WER model equation across a range of DOC and alkalinity concentrations (including alkalinity concentrations less than 27 mg/L; the minimum of the model range). This clearly shows that, depending on DOC concentrations, SSC values calculated at low alkalinities (i.e., less than 10 mg/L) can be much lower than SSC values calculated at 27 mg/L, thereby providing an environmentally conservative way to handle alkalinity values less than the model range.

An evaluation of STSIU surface-water chemistry variability is provided in **Appendix E**. Samples available for the evaluation include STSIU surface-water samples collected during the monsoon season in three different years (2010, 2011, and 2013). During the 2011 WER sampling, water chemistry was collected at five additional sample locations (in addition to the 18 WER sampling locations) to increase the spatial distribution of chemistry samples in the STSIU study area (toxicity tests were not performed on these five additional locations). Chemistry samples were also collected during the 2010 Wet Season Survey, which was performed during the planning phases of the current study to gain a better understanding of Site-water chemistries. Last, samples were collected during August 2013 to support this evaluation. As described in **Appendix E**, drainage areas sampled in 2013 contained more water than previous years due to strong monsoonal precipitation that occur prior to, and during, the 2013 sampling effort. Previous STSIU surface-water investigations (i.e., *the STSIU Remedial Investigation and Ecological Risk Assessment*) primarily evaluated metal compliance trends, and therefore did not sample all chemical parameters necessary to compare with the model range.

In total, 49 distinct surface-water samples have been collected in the STSIU study area and analyzed for the complete set of water chemistries (including alkalinity and DOC model parameters). This includes the 17 samples used to develop the WER model and 32 additional samples collected to evaluate water chemistry characteristics. Overall, this evaluation indicates that the range of chemistry used to develop the WER model (i.e., the range of DOC and alkalinity measured in the 17 toxicity tests conducted using various STSIU surface waters) is representative of the range of chemistries typically observed in the STSIU surface waters. Additionally, **Appendix E** shows that the range of other parameters determined in this study to be significant predictors of Site-specific toxicity (i.e., TOC, Hardness/Alkalinity and TSS) also compared well with ambient samples collected across STSIU.

The WER model was developed from chemistry and toxicity data collected across eight sub-watershed units during two distinct sampling events in the 2011 monsoon season. As a result, this model is based on a wide spatial range of STSIU surface-water samples. Given the limited persistence of water in the STSIU drainages, and limitations associated with the lack of water in many of these drainages during the dry season (and the lack of water in many portions of these drainages during the wet season), these samples also provide a temporal range representative of local climate and hydrology. Therefore, the current model is calibrated to a sufficient temporal and spatial range for application to STSIU surface waters.

As stated previously, an advantage of the model is that it predicts toxicity well across the wide range of water chemistry values that thus far have been recorded for STSIU waters. That is, model-predicted EC50 values are a function of water chemistry values (analogous to hardness-based criteria or BLM-based predictions, which also are considered to be applicable across the entire range of water chemistry with which they were calibrated). For this reason, water chemistry variability within STSIU is not expected to be a limitation of this model-based approach; instead, site-specific criteria values derived from this model-based approach will be reflective of the water chemistry variability expected at STSIU.

4.2.2.3 Geographic Extent of Model Application

Some additional background information will be useful to this discussion. The STSIU study area was established as part of the AOC to address potential releases of mining-related constituents to the surrounding landscape. The conceptual site model for STSIU identified fugitive dust emissions from the smelter as the primary source of contamination to STSIU soils and drainage areas. The smelter is no longer an active source of contamination because it was dismantled in 2007 (active smelting operations ceased in 2002). Copper is the primary constituent of concern within the STSIU area (SRK 2008).

The STSIU surface-water drainages evaluated in this study and proposed for SSC application were not contaminated by point-sources of contamination such as discharges or tailings. Instead, these drainages were contaminated by a diffuse, non-point source of copper contamination (i.e., historic emissions). Based on previous Site investigations, including a recently completed hydrology-based Use Attainability Analysis (UAA) (ARCADIS 2013c), most surface-water drainages in the STSIU area are characterized as ephemeral, flowing only in direct response to monsoonal precipitation. As a result, surface waters in STSIU have limited temporal and spatial persistence. Besides direct storm flow runoff, STSIU surface-water environments consist of isolated pools, typically located in the higher elevations of STSIU and within predominately bedrock channels. This has been observed consistently throughout



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various Site investigations, including the surface-water sampling conducted to support this study.

From information collected in this study and previous Site investigations, the surface-water sample locations discussed and graphically depicted in Appendix E largely represent the drainage locations where surface-water pools tend to exist in STSIU, particularly during the wet season (since most of these locations are completely dry outside of the wet season). Because of this, the available surface-water chemistry data, collected across a wide spatial and temporal range, provides a strong representation of the types and chemistry of available surface waters in STSIU.

Appendix E shows that the chemistry range used to develop the model sufficiently represents the range of ambient surface waters in the STSIU study area. Therefore, the recommended geographic range for model application is the STSIU study area (**Figure 1**), excluding any portion of Hanover and Whitewater Creeks. Application of this model to surface waters outside of the STSIU study area is not recommended or proposed because the model is calibrated to the specific chemistry of STSIU surface waters, which is distinct from other surrounding surface waters given the unique geologic, hydrologic and upland characteristics of the STSIU area. For example, Hanover and Whitewater Creeks, the primary adjacent surface waters to STSIU, are characterized by substantially greater water hardness concentrations compared to STSIU surface waters and the range used to develop the WER model.

4.2.2.4 Protectiveness Inherent in Criteria Derivation

The proposed WER-model approach does not decrease any of the protectiveness inherent in the process of derivation of water quality criteria that is prescribed in USEPA (1985), including protecting 95% of the species, dividing the final acute value (FAV) by 2 to derive an acute criterion, and dividing the FAV by the acute-chronic ratio to derive a chronic criterion. Accounting for the toxicity-modifying effects of water chemistry parameters (which is all the proposed WER-model approach does) will not decrease the protectiveness of the criteria-derivation procedure.

5. Conclusions and Recommendations

The conceptual approach of developing a WER model that can be applied to STSIU surface waters was presented in the ARCADIS (2011) work plan. By letter dated September 1, 2011, NMED provided comments to this work plan and expressed agreement with a general WER-model approach, recognizing that the nature of this study differs significantly from the specific scenarios addressed in the USEPA (1994)



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WER guidance. Results from the studies described in that work plan were evaluated against USEPA WER acceptability criteria and fully reported in the Interim Report (ARCADIS 2013a).

Using the chemistry and toxicity data reported in ARCADIS (2013a), a draft version of this report was submitted to NMED SWQB in April 2013, prior to the June 10 2013 meeting between Chino and NMED SWQB that was mostly focused on this WER model approach. Based on discussions from that meeting and from NMED SWQB comments to the draft report (dated July 1, 2013), this current revised Copper Toxicity Model report provides the statistical basis and specific guidelines for implementing a WER model to derive copper SSC that can be applied to STSIU surface waters. The sampling and toxicity testing methods, proposed WER model, and recommendations for implementing the proposed WER model are consistent with the general WER-model approach discussed in previous reports.

The proposed WER model was selected based on statistical relations between Site chemistry and measured toxicity and by linking these relations to the dominant mechanisms of copper toxicity that occur within the specific range of STSIU water chemistries. From a statistical standpoint, the proposed model was determined as the best-fit statistical model based on the level of statistical significance associated with MLR analysis, by evaluating the co-linearity of input parameters, and by considering the accuracy of model predictions. Additionally, recommendations for implementing the model are based on an understanding of the hydrology, upland properties, nature and extent of contamination, and surface-water chemistry that is known to occur throughout the study area.

Regarding model-input parameters, NMED's comments to the ARCADIS (2011) work plan suggested that TSS and pH be evaluated in addition to dissolved organic carbon, hardness, and alkalinity. These parameters are discussed in Section 3, and the statistical results are listed in **Table 3** and **Appendices B, C, and D** (in addition to evaluations of other model input parameters not specifically identified by NMED comments). Based on this evaluation, it is concluded that although these water chemistry parameters (as well as other water chemistry parameters) can affect copper toxicity, they are not significant drivers or reliable predictors of copper toxicity within STSIU surface waters.

Including TSS and pH as model parameters did not provide a better-fit model based on these analyses; neither of these parameters was significantly associated with observed toxicity values (judged by the level of statistical significance of each parameter in the MLR models and based on the Pearson Correlation summary). In fact, pH should have little direct effect on copper toxicity at pH values above approximately 6.5, because hydrogen ions (H^+ , of which pH is an index) are not an effective competitor for



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binding to biotic ligands until the pH is below approximately 6.5 (because H^+ concentration increases as pH decreases). Therefore, at pH values characteristic of most STSIU waters, H^+ ions provide relatively little protection against copper toxicity. In contrast, pH can have an important indirect effect on copper bioavailability by changing the bicarbonate/carbonate (HCO_3^-/CO_3^{2-}) ratio in the exposure water and leading to higher concentrations of carbonate (which has a higher affinity for copper than bicarbonate has) at higher pH values. However, because alkalinity generally increases as pH increases, the two parameters usually are well-correlated. Therefore, inclusion of pH and alkalinity in a statistical-based model would be duplicative and might cause the model to be unstable because of high co-linearity between the two predictor variables.

As proposed in the work plan, BLM evaluations were also performed on water samples used in the toxicity tests; and these results were summarized in this report. These BLM analyses confirmed general correlation and regression trends observed between water chemistry and toxicity values, and provided additional verification of the WER model's performance. On the basis of model accuracy, the MLR model approach was determined to provide better predictions, without systematically over- or under-predicting toxicity values (in contrast to the BLM that systematically under-predicted toxicity [i.e., the BLM predicted higher EC50 values than the measured EC50 values]).

In conclusion, this report proposes a specific WER model that can be applied to STSIU surface waters to derive site-specific copper criteria. The proposed model has high predictability and covers wide temporal and spatial conditions found in STSIU surface waters. As demonstrated in this report, the specific implementation steps and margin of safety recommendations proposed herein for deriving and applying SSC to STSIU surface waters provides a technically-defensible basis to address Site-specific challenges, while also providing for environmentally conservative SSC. Therefore, Chino recommends that NMED adopt this MLR-model approach for deriving SSC in STSIU surface waters.

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Tables

**TABLE 1
SUMMARY OF MEASURED DISSOLVED COPPER CONCENTRATIONS AND COPPER COMPLIANCE EVALUATIONS BASED ON THE
HARDNESS CMC AND WER-ADJUSTED CMC**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Sample ID | Dissolved Cu (µg/L) | Dissolved Cu WER ¹ | Hardness (mg/L as CaCO ₃) | Dissolved Cu Hardness CMC ² | Hardness-Based Cu CMC Compliance Ratio ³ | WER-Adjusted Cu CMC Compliance Ratio ⁴ |
|-----------|---------------------|-------------------------------|---------------------------------------|--|---|---|
| 1-1 | 5.9 | 6.651 | 90 | 12.2 | 0.48 | 0.07 |
| 1-2 | 6.5 | 5.334 | 84 | 11.4 | 0.57 | 0.11 |
| 1-D1-2 | 32.3 | 13.104 | 54 | 7.5 | 4.30 | 0.33 |
| 1-D2-1 | 32.8 | 8.027 | 42 | 5.9 | 5.53 | 0.69 |
| 1-6 | 57.4 | 14.407 | 54 | 7.5 | 7.63 | 0.53 |
| 1-7 | 43.0 | 4.717 | 106 | 14.2 | 3.03 | 0.64 |
| 1-9 | 7.1 | 2.207 | 88 | 11.9 | 0.60 | 0.27 |
| 1-10 | 5.4 | 2.804 | 262 | 33.3 | 0.16 | 0.06 |
| 1-11 | 4.3 | 5.956 | 154 | 20.2 | 0.21 | 0.04 |
| 1-12 | 2.1 | 0.989 | 76 | 10.4 | 0.20 | 0.20 |
| 1-RCS1 | 5.0 | 3.273 | 48 | 6.7 | 0.74 | 0.23 |
| 2-1 | 3.4 | 4.046 | 104 | 13.9 | 0.24 | 0.06 |
| 2-6 | 30.2 | 6.151 | 50 | 7.0 | 4.32 | 0.70 |
| 2-D1-2 | 17.9 | 5.724 | 60 | 8.3 | 2.16 | 0.38 |
| 2-9 | 13.7 | 11.530 | 82 | 11.1 | 1.23 | 0.11 |
| 2-11 | 7.9 | 6.889 | 102 | 13.7 | 0.58 | 0.08 |
| 2-12 | 3.6 | 2.251 | 80 | 10.9 | 0.33 | 0.15 |

Notes:

¹ WER = Site water EC50 / 19.31 (SMAV reported by USEPA (2001)).

² Dissolved Cu CMC = $\exp(0.9422(\ln(\text{hardness}))-1.7)(0.96)$

³ Hardness-based Cu CMC compliance ratio = Dissolved Cu / Hardness-Based CMC

⁴ WER-adjusted Cu CMC compliance ratio = Dissolved Cu / (WER x hardness-based Cu CMC)

CMC = criteria maximum concentration

SMAV = species mean acute value

WER = water effect ratio

TABLE 2
ANALYTICAL CHEMISTRY RESULTS AND TOXICITY ENDPOINTS MEASURED IN WER SAMPLES AND USED TO DEVELOP THE PROPOSED WER MODEL

FREEDPORT ANCHORAGE CHINO MINES COMPANY
VANADUM, NEW MEXICO
SMELTER/TAILINGS SOILS IN-SITE SPECIFIC COPPER TOXICITY MODEL REPORT

| Parameters / Sample No. | Round 1 (2007) | | | | | | | | | | Round 2 (2008) | | | | | | | | | |
|---------------------------------------|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|----------------|-------|-------|-------|--------|-------|-------|-------|----|----|
| | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Major Cations (mg/L) | | | | | | | | | | | | | | | | | | | | |
| Calcium, dissolved | 23.7 | 20 | 17.2 | 12.3 | 26.3 | 19.1 | 56.6 | 34.0 | 17.4 | 9.9 | 13.9 | 11.6 | 25.2 | 10.5 | 18.9 | 25.6 | 15.9 | 14.9 | | |
| Calcium, total | 24.6 | 20.7 | 17.4 | 12.7 | 27.1 | 19.5 | 57.7 | 35.9 | 18.5 | 10.5 | 14.2 | 11.8 | 26.3 | 11 | 19.8 | 26.7 | 19.7 | 15.7 | | |
| Magnesium, dissolved | 7.7 | 7.6 | 5.2 | 5.7 | 10.3 | 9.3 | 28.2 | 18.6 | 7.4 | 4.8 | 4.2 | 3.7 | 8.2 | 5.1 | 9.3 | 13.3 | 7 | 4.8 | | |
| Magnesium, total | 8.1 | 7.9 | 5.5 | 5.9 | 10.7 | 9.5 | 28.7 | 19.2 | 7.9 | 5.1 | 4.2 | 3.9 | 8.6 | 5.4 | 10 | 14.1 | 8.6 | 5.1 | | |
| Potassium, dissolved | 3 | 2.5 | 3.6 | 3.7 | 5.2 | 3.5 | 4 | 6.9 | 3.1 | 2.3 | 3.0 | 3.3 | 2.6 | 3.1 | 8.4 | 5.2 | 2.8 | 2.8 | | |
| Sodium, dissolved | 18.7 | 17.6 | 14.5 | 7.2 | 8.8 | 9.4 | 32.7 | 10.5 | 6.3 | 5.2 | 17.8 | 12.1 | 20.2 | 6.4 | 10.5 | 7.8 | 7.4 | 17.1 | | |
| Trace Metals (mg/L) | | | | | | | | | | | | | | | | | | | | |
| Aluminum, dissolved | 4 | 6 | 7 | 12 | 7 | 4 | 2 | 21 | 5 | <1 | 42 | 18 | <1 | 5 | 7 | 10 | 8 | <1 | | |
| Aluminum, total | 32 | 33 | 283 | 87 | 200 | 87 | 32 | 741 | 85 | 14 | 712 | 11600 | 39 | 282 | 307 | 1200 | 123 | 1000 | | |
| Cadmium, dissolved | <0.1 | <0.1 | 0.2 | <0.1 | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | | |
| Cadmium, total | <0.1 | <0.1 | 0.3 | <0.1 | 0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | | |
| Copper, dissolved | 5.9 | 6.5 | 32.3 | 57.4 | 43 | 7.1 | 5.4 | 4.3 | 2.1 | 5 | 32.3 | 32.8 | 3.4 | 30.2 | 13.7 | 7.9 | 3.5 | 17.9 | | |
| Copper, total | 7.1 | 8 | 63.1 | 133 | 66.6 | 8.8 | 7.1 | 5.8 | 3 | 6 | 111.3 | 102.2 | 4.2 | 48.5 | 20.7 | 10.7 | 4.9 | 43 | | |
| Iron, dissolved | 90 | <30 | 40 | 80 | <30 | <30 | <30 | <30 | <30 | <30 | 150 | 40 | <30 | 40 | 30 | <30 | <30 | 20 | | |
| Iron, total | 230 | 80 | 330 | 410 | 300 | 80 | <30 | 460 | 40 | <30 | 580 | 1320 | 130 | 400 | 430 | 800 | 70 | 870 | | |
| Lead, dissolved | <0.1 | <0.1 | 0.3 | 0.4 | 0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 0.5 | 0.4 | <0.1 | <0.1 | 0.2 | 0.2 | 0.2 | <0.1 | | |
| Lead, total | 0.4 | 0.4 | 0.3 | 0.3 | 0.2 | <0.1 | <0.1 | 0.3 | <0.1 | <0.1 | 0.7 | 0.9 | <0.1 | 0.2 | 0.5 | 0.3 | <0.1 | 0.9 | | |
| Manganese, dissolved | 21.6 | 46.8 | 72.7 | 18.2 | 52.1 | 16.3 | 18.4 | 188.6 | 12.2 | 3 | 19.3 | 182.3 | 3.2 | 17.8 | 33.7 | 30.8 | 18.1 | 11 | | |
| Manganese, total | 36.9 | 71.1 | 137.2 | 74.9 | 171.4 | 93 | 28.6 | 258 | 14.7 | 17.7 | 46.7 | 195.5 | 55.4 | 70.9 | 201 | 119.6 | 24.7 | 38.1 | | |
| Zinc, dissolved | 3 | 3 | 8 | 4 | 3 | 3 | 3 | 3 | 3 | <2 | 3 | 8 | 2 | 3 | 2 | 15 | 4 | 2 | | |
| Zinc, total | 4 | 3 | 10 | 4 | 4 | <2 | 2 | 3 | 4 | 4 | 8 | 7 | 4 | 3 | 3 | 4 | 3 | 7 | | |
| Water Chemistry (mg/L) | | | | | | | | | | | | | | | | | | | | |
| Bicarbonate as CaCO3 (mg/L) | 58 | 56 | 24 | 41 | 63 | 87 | 232 | 183 | 27 | 26 | 74 | 24 | 80 | 36 | 90 | 102 | 31 | 60 | | |
| Dissolved organic carbon (DOC) (mg/L) | 10.7 | 7.8 | 3.5 | 12.5 | 7.8 | 2.6 | 4.7 | 15.7 | 1.2 | 3.2 | 10.0 | 5.8 | 11 | 11.4 | 12.3 | 12.3 | 3.1 | 10.5 | | |
| Total organic carbon (TOC) (mg/L) | 16.2 | 8 | 3.7 | 14.9 | 6.8 | 3.2 | 4.8 | 14.3 | 3 | 4.3 | 9.0 | 6.0 | 11.2 | 10.2 | 15.1 | 13.5 | 6.5 | 6.4 | | |
| Carbonate as CaCO3 (mg/L) | <2 | <2 | <2 | <2 | <2 | 8 | 3 | <2 | 3 | <2 | <2 | <2 | <2 | 5 | <2 | <2 | <2 | <2 | | |
| Carbon-Anion Balance % | 3.8 | 2.1 | 2.6 | 3.4 | -1.9 | 2.8 | 3.1 | 4 | 2.7 | 0 | 5.6 | 7.1 | 0 | 4 | 2.2 | 3.7 | -5.1 | 0 | | |
| Chloride (mg/L) | 7 | 7 | 4 | 4 | 4 | 2 | 15 | 8 | 3 | <1 | 3 | 3 | 8 | 2 | 8 | 6 | 3 | 2 | | |
| Hardness as CaCO3 (mg/L) | 91 | 81 | 64 | 54 | 108 | 86 | 237 | 184 | 74 | 45 | 82 | 44 | 97 | 47 | 86 | 119 | 80 | 67 | | |
| Hydrosulfide as CaCO3 (mg/L) | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | | |
| pH ¹ | 8.2 | 7.8 | 7.5 | 7.5 | 8.0 | 8.2 | 8.5 | 8.3 | 7.2 | 8.6 | 7.9 | 7.0 | 8.2 | 7.5 | 8.5 | 8.1 | 7.7 | 8 | | |
| Total dissolved solids (TDS) (mg/L) | 200 | 200 | 180 | 130 | 210 | 150 | 390 | 240 | 150 | 90 | 150 | 180 | 210 | 190 | 200 | 190 | 170 | 170 | | |
| Total suspended solids (TSS) (mg/L) | <5 | <5 | 5 | <5 | 8 | <5 | 8 | 10 | <5 | <5 | 5 | <5 | <5 | 10 | 6 | 12 | 8 | 8 | | |
| Sulfate (mg/L) | 48 | 48 | 65 | 23 | 64 | 17 | 83 | 16 | 58 | 25 | 9 | 37 | 40.7 | 23.3 | 8.7 | 22.5 | 84.4 | 31.8 | | |
| Sum of Anions (meq/L) | 2.5 | 2.3 | 1.9 | 1.4 | 2.7 | 2.1 | 6.2 | 3.6 | 1.8 | 1.1 | 1.7 | 1.3 | 2.8 | 1.2 | 2.2 | 2.6 | 2 | 1.9 | | |
| Sum of Cations (meq/L) | 2.7 | 2.4 | 2.0 | 1.5 | 2.6 | 2.2 | 6.6 | 3.9 | 1.9 | 1.1 | 1.9 | 1.5 | 2.8 | 1.3 | 2.3 | 2.8 | 1.7 | 1.9 | | |
| Total Alkalinity (mg/L) | 68 | 66 | 24 | 41 | 63 | 87 | 238 | 156 | 27 | 30 | 74 | 24 | 80 | 36 | 95 | 102 | 31 | 60 | | |
| Water Chemistry (°C) | | | | | | | | | | | | | | | | | | | | |
| Analysis Temperature °C | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | | |
| Total Hardness (mg CaCO3/L) | 90 | 84 | 62 | 54 | 106 | 88 | 282 | 154 | 76 | 46 | 64 | 42 | 104 | 80 | 82 | 102 | 80 | 60 | | |
| pH | 8 | 7.47 | 7.64 | 7.67 | 7.93 | 8.04 | 8.31 | 8.22 | 8.35 | 8.67 | 8.08 | 8.10 | 8.10 | 7.14 | 8.44 | 7.90 | 7.4 | 7.82 | | |
| Alkalinity (mg CaCO3/L) | 74 | 60 | 28 | 42 | 66 | 90 | 230 | 170 | 104 | 32 | 78 | 28 | 86 | 40 | 102 | 106 | 34 | 64 | | |
| Conductivity (mS/cm) | 0.274 | 0.265 | 0.222 | 0.159 | 0.277 | 0.224 | 0.590 | 0.378 | 0.224 | 0.134 | 0.190 | 0.188 | 0.294 | 0.145 | 0.242 | 0.287 | 0.234 | 0.21 | | |
| Total Dissolved Solids (mg/L) | 134 | 130 | 109 | 78 | 138 | 110 | 289 | 184 | 110 | 68 | 83 | 82 | 144 | 71 | 119 | 141 | 115 | 103 | | |
| Dissolved Oxygen (mg/L) | 8.3 | 7.5 | 7.2 | 7 | 7.2 | 7.2 | 7.8 | 7.3 | 7.6 | 8.5 | 6.9 | 6.8 | 8.1 | 7.4 | 7.2 | 7.2 | 7.2 | 7.4 | | |
| Dissolved copper EC50 (µg/L) | | | | | | | | | | | | | | | | | | | | |
| Dissolved copper EC50 (µg/L) | 116.3 | 87.4 | <32.3 | 155.7 | 96.2 | 37.8 | 134.2 | 172.2 | 14.7 | 31.7 | 141.6 | 68.4 | 81.06 | 61.82 | >184.7 | 135.5 | 35.23 | 68.31 | | |

¹ Analytic associated method hold time. pH is a field test with no hold time.
² Based on the hardness values measured upon sample collection and test inhibition this measured alkalinity value is considered accurate (ACZ-measured alkalinity of 27 mg/L used for regressions).
³ No exposure treatment adversely affected more than 50% of test organisms; therefore the EC50 concentration is less than the lowest Cu concentration.
⁴ No exposure treatment adversely affected more than 50% of test organisms; therefore the EC50 concentration is greater than the highest Cu concentration.
 Bolded values: analyte concentration detected at a value between a MDL and PQL. The associated value is an estimated quantity.
 < values - the analyte was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantification limit or the sample detection limit.
 mg/L = milligrams per liter.
 µg/L = micrograms per liter.
 °C = degrees Celsius.
 mg CaCO3/L = milligrams calcium carbonate per liter.
 mS/cm = millisiemens per centimeter.
 mg NH3/L = milligrams ammonia per liter.

TABLE 3
Statistical Summaries of Step-Wise Multiple Linear Regression Analysis

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Summary of additional multiple regression analyses performed for WER model evaluation.

| 1. Input Parameters: TOC, Hardness/Alkalinity, TDS | | | | | | |
|---|-------------|------------|---------|---------|-------|--|
| R² = 0.869 | | | | | | |
| Adj R² = 0.838 | | | | | | |
| Regression p-value = < 0.001 | | | | | | |
| Log LC50 = -0.128 + (0.703 * log TOC) - (0.787 * log (H/A)) + (0.653 * log TDS) | | | | | | |
| | Coefficient | Std. Error | t | p-value | VIF | |
| Constant | -0.128 | 0.536 | -0.238 | 0.815 | | |
| log TOC | 0.703 | 0.149 | 4.718 | <0.001 | 1.302 | |
| log (H/A) | -0.787 | 0.226 | -3.485 | 0.004 | 1.336 | |
| log TDS | 0.653 | 0.233 | 2.8 | 0.015 | 1.073 | |
| 2. Input Parameters: DOC, Hardness/Alkalinity, TDS | | | | | | |
| R² = 0.868 | | | | | | |
| Adj R² = 0.838 | | | | | | |
| Regression p-value = < 0.001 | | | | | | |
| Log LC50 = -0.0439 + (0.633 * log DOC) - (0.438 * log (H/A)) + (0.645 * log TDS) | | | | | | |
| | Coefficient | Std. Error | t | P | VIF | |
| Constant | -0.0439 | 0.534 | -0.0822 | 0.936 | | |
| log DOC | 0.633 | 0.135 | 4.701 | <0.001 | 1.865 | |
| log (H/A) | -0.438 | 0.268 | -1.631 | 0.127 | 1.878 | |
| log TDS | 0.645 | 0.234 | 2.759 | 0.016 | 1.075 | |
| 3. Input Parameters: TOC, Hardness/Alkalinity, TDS, pH | | | | | | |
| R² = 0.871 | | | | | | |
| Adj R² = 0.828 | | | | | | |
| Regression p-value = < 0.001 | | | | | | |
| Log LC50 = 0.122 + (0.674 * log TOC) - (0.790 * log (H/A)) + (0.663 * log TDS) - (0.0308 * pH) | | | | | | |
| | Coefficient | Std. Error | t | P | VIF | |
| Constant | 0.122 | 0.778 | 0.157 | 0.878 | | |
| log TOC | 0.674 | 0.166 | 4.051 | 0.002 | 1.524 | |
| log (H/A) | -0.79 | 0.233 | -3.39 | 0.005 | 1.338 | |
| log TDS | 0.663 | 0.242 | 2.746 | 0.018 | 1.083 | |
| pH | -0.0308 | 0.0674 | -0.458 | 0.655 | 1.202 | |
| 4. Input Parameters: DOC, Hardness/Alkalinity, TDS, pH | | | | | | |
| R² = 0.869 | | | | | | |
| Adj R² = 0.826 | | | | | | |
| Regression p-value = < 0.001 | | | | | | |
| Log LC50 = -0.254 + (0.664 * log DOC) - (0.411 * log (H/A)) + (0.634 * log TDS) + (0.0256 * pH) | | | | | | |
| | Coefficient | Std. Error | t | P | VIF | |
| Constant | -0.254 | 0.824 | -0.309 | 0.763 | | |
| log DOC | 0.664 | 0.166 | 4.009 | 0.002 | 2.628 | |
| log (H/A) | -0.411 | 0.288 | -1.426 | 0.179 | 2.021 | |
| log TDS | 0.634 | 0.244 | 2.598 | 0.023 | 1.092 | |
| pH | 0.0256 | 0.0744 | 0.344 | 0.736 | 1.447 | |

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| 5. Input Parameters: TOC, Hardness/Alkalinity, (TDS + TSS) | | | | | |
|--|-------------|------------|---------|--------|-------|
| R² = 0.869 | | | | | |
| Adj R² = 0.838 | | | | | |
| Regression p-value = < 0.001 | | | | | |
| Log LC50 = -0.126 + (0.700 * log TOC) - (0.794 * log (H/A)) + (0.650 * Log TDS+TSS) | | | | | |
| | Coefficient | Std. Error | t | P | VIF |
| Constant | -0.126 | 0.536 | -0.235 | 0.818 | |
| log TOC | 0.7 | 0.149 | 4.692 | <0.001 | 1.304 |
| log (H/A) | -0.794 | 0.226 | -3.517 | 0.004 | 1.332 |
| Log TDS+TSS | 0.65 | 0.232 | 2.796 | 0.015 | 1.071 |
| 6. Input Parameters: DOC, Hardness/Alkalinity, (TDS + TSS) | | | | | |
| R² = 0.867 | | | | | |
| Adj R² = 0.837 | | | | | |
| Regression p-value = < 0.001 | | | | | |
| Log LC50 = -0.0365 + (0.630 * log DOC) - (0.447 * log (H/A)) + (0.640 * Log TDS+TSS) | | | | | |
| | Coefficient | Std. Error | t | P | VIF |
| Constant | -0.0365 | 0.536 | -0.0682 | 0.947 | |
| log DOC | 0.63 | 0.135 | 4.658 | <0.001 | 1.868 |
| log (H/A) | -0.447 | 0.269 | -1.662 | 0.12 | 1.872 |
| Log TDS+TSS | 0.64 | 0.234 | 2.737 | 0.017 | 1.073 |
| 7. Input Parameters: TOC, Hardness/Alkalinity, TSS, pH | | | | | |
| R² = 0.815 | | | | | |
| Adj R² = 0.753 | | | | | |
| Regression p-value = < 0.001 | | | | | |
| Log LC50 = 1.330 + (0.697 * log TOC) - (0.907 * log (H/A)) + (0.176 * Log TSS) - (0.0110 * pH) | | | | | |
| | Coefficient | Std. Error | t | P | VIF |
| Constant | 1.33 | 0.741 | 1.794 | 0.098 | |
| log TOC | 0.697 | 0.199 | 3.5 | 0.004 | 1.524 |
| log (H/A) | -0.907 | 0.275 | -3.299 | 0.006 | 1.295 |
| Log TSS | 0.176 | 0.139 | 1.267 | 0.229 | 1.022 |
| pH | -0.011 | 0.0804 | -0.137 | 0.893 | 1.191 |
| 8. Input Parameters: DOC, Hardness/Alkalinity, TSS, pH | | | | | |
| R² = 0.811 | | | | | |
| Adj R² = 0.748 | | | | | |
| Regression p-value = < 0.001 | | | | | |
| Log LC50 = 0.906 + (0.689 * log DOC) - (0.509 * log (H/A)) + (0.137 * Log TSS) + (0.0460 * pH) | | | | | |
| | Coefficient | Std. Error | t | P | VIF |
| Constant | 0.906 | 0.828 | 1.094 | 0.296 | |
| log DOC | 0.689 | 0.201 | 3.427 | 0.005 | 2.672 |
| log (H/A) | -0.509 | 0.348 | -1.465 | 0.169 | 2.027 |
| Log TSS | 0.137 | 0.142 | 0.97 | 0.351 | 1.047 |
| pH | 0.046 | 0.0889 | 0.518 | 0.614 | 1.427 |

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| 9. Input Parameters: TOC, Hardness/Alkalinity, TSS | | | | | |
|--|-------------|------------|--------|--------|-------|
| R² = 0.814 | | | | | |
| Adj R² = 0.772 | | | | | |
| Regression p-value = < 0.001 | | | | | |
| Log LC50 = 1.232 + (0.707 * log TOC) - (0.905 * log (H/A)) + (0.176 * Log TSS) | | | | | |
| | Coefficient | Std. Error | t | P | VIF |
| Constant | 1.232 | 0.186 | 6.631 | <0.001 | |
| log TOC | 0.707 | 0.178 | 3.975 | 0.002 | 1.315 |
| log (H/A) | -0.905 | 0.264 | -3.428 | 0.004 | 1.293 |
| Log TSS | 0.176 | 0.133 | 1.321 | 0.209 | 1.021 |
| 10. Input Parameters: DOC, Hardness/Alkalinity, TSS | | | | | |
| R² = 0.807 | | | | | |
| Adj R² = 0.762 | | | | | |
| Regression p-value = < 0.001 | | | | | |
| Log LC50 = 1.325 + (0.634 * log DOC) - (0.560 * log (H/A)) + (0.141 * Log TSS) | | | | | |
| | Coefficient | Std. Error | t | P | VIF |
| Constant | 1.325 | 0.172 | 7.715 | <0.001 | |
| log DOC | 0.634 | 0.166 | 3.825 | 0.002 | 1.925 |
| log (H/A) | -0.56 | 0.324 | -1.73 | 0.107 | 1.864 |
| Log TSS | 0.141 | 0.138 | 1.025 | 0.324 | 1.045 |
| 11. Input Parameters: TOC, Hardness, Alkalinity, TSS | | | | | |
| R² = 0.844 | | | | | |
| Adj R² = 0.792 | | | | | |
| Regression p-value = < 0.001 | | | | | |
| Log LC50 = 0.705 + (0.730 * log TOC) - (0.549 * log Hardness) + (0.837 * log Alkalinity) + (0.102 * Log TSS) | | | | | |
| | Coefficient | Std. Error | t | P | VIF |
| Constant | 0.705 | 0.39 | 1.807 | 0.096 | |
| log TOC | 0.73 | 0.17 | 4.286 | 0.001 | 1.325 |
| log Hardness | -0.549 | 0.344 | -1.596 | 0.136 | 3.899 |
| log Alkalinity | 0.837 | 0.256 | 3.271 | 0.007 | 4.052 |
| Log TSS | 0.102 | 0.136 | 0.752 | 0.467 | 1.171 |
| 12. Input Parameters: DOC, Hardness, Alkalinity, TSS | | | | | |
| R² = 0.855 | | | | | |
| Adj R² = 0.807 | | | | | |
| Regression p-value = < 0.001 | | | | | |
| Log LC50 = 0.621 + (0.690 * log DOC) - (0.0456 * log Hardness) + (0.417 * log Alkalinity) + (0.0393 * Log TSS) | | | | | |
| | Coefficient | Std. Error | t | P | VIF |
| Constant | 0.621 | 0.383 | 1.621 | 0.131 | |
| log DOC | 0.69 | 0.152 | 4.545 | <0.001 | 1.992 |
| log Hardness | -0.0456 | 0.388 | -0.117 | 0.908 | 5.334 |
| log Alkalinity | 0.417 | 0.3 | 1.39 | 0.19 | 5.998 |
| log TSS | 0.0393 | 0.134 | 0.294 | 0.774 | 1.22 |

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| 13. Input Parameters: TOC, Hardness, Alkalinity, TSS, pH | | | | | | |
|--|--------------------|-------------------|----------|----------|--|------------|
| R² = 0.847 | | | | | | |
| Adj R² = 0.778 | | | | | | |
| Regression p-value = < 0.001 | | | | | | |
| Log LC50 = 0.993 + (0.698 * log TOC) - (0.530 * log Hardness) + (0.838 * log Alkalinity) + (0.0960 * Log TSS) - (0.0365 * pH) | | | | | | |
| | Coefficient | Std. Error | t | P | | VIF |
| Constant | 0.993 | 0.736 | 1.348 | 0.205 | | |
| log TOC | 0.698 | 0.189 | 3.695 | 0.004 | | 1.524 |
| log Hardness | -0.53 | 0.358 | -1.481 | 0.167 | | 3.949 |
| log Alkalinity | 0.838 | 0.265 | 3.167 | 0.009 | | 4.053 |
| log TSS | 0.096 | 0.141 | 0.68 | 0.511 | | 1.181 |
| pH | -0.0365 | 0.078 | -0.468 | 0.649 | | 1.247 |
| 14. Input Parameters: DOC, Hardness, Alkalinity, TSS, pH | | | | | | |
| R² = 0.856 | | | | | | |
| Adj R² = 0.791 | | | | | | |
| Regression p-value = < 0.001 | | | | | | |
| Log LC50 = 0.437 + (0.715 * log DOC) - (0.0328 * log Hardness) + (0.396 * log Alkalinity) + (0.0399 * Log TSS) + (0.0219 * pH) | | | | | | |
| | Coefficient | Std. Error | t | P | | VIF |
| Constant | 0.437 | 0.795 | 0.55 | 0.593 | | |
| log DOC | 0.715 | 0.184 | 3.894 | 0.003 | | 2.687 |
| log Hardness | -0.0328 | 0.407 | -0.0806 | 0.937 | | 5.41 |
| log Alkalinity | 0.396 | 0.322 | 1.229 | 0.245 | | 6.381 |
| log TSS | 0.0399 | 0.139 | 0.286 | 0.78 | | 1.22 |
| pH | 0.0219 | 0.082 | 0.267 | 0.795 | | 1.463 |
| 15. Input Parameters: TOC, Alkalinity, TDS | | | | | | |
| R² = 0.810 | | | | | | |
| Adj R² = 0.766 | | | | | | |
| Regression p-value = < 0.001 | | | | | | |
| Log LC50 = 0.0802 + (0.846 * log TOC) + (0.471 * log Alkalinity) + (0.0904 * log TDS) | | | | | | |
| | Coefficient | Std. Error | t | P | | VIF |
| Constant | 0.0802 | 0.724 | 0.111 | 0.914 | | |
| log TOC | 0.846 | 0.166 | 5.107 | <0.001 | | 1.114 |
| log Alkalinity | 0.471 | 0.225 | 2.096 | 0.056 | | 2.775 |
| log TDS | 0.0904 | 0.437 | 0.207 | 0.839 | | 2.605 |
| 16. Input Parameters: DOC, Alkalinity, TDS | | | | | | |
| R² = 0.861 | | | | | | |
| Adj R² = 0.829 | | | | | | |
| Regression p-value = <0.001 | | | | | | |
| Log LC50 = 0.134 + (0.718 * log DOC) + (0.273 * log Alkalinity) + (0.296 * log TDS) | | | | | | |
| | Coefficient | Std. Error | t | P | | VIF |
| Constant | 0.134 | 0.618 | 0.217 | 0.832 | | |
| log DOC | 0.718 | 0.113 | 6.347 | <0.001 | | 1.246 |
| log Alkalinity | 0.273 | 0.202 | 1.353 | 0.199 | | 3.046 |
| log TDS | 0.296 | 0.378 | 0.783 | 0.448 | | 2.659 |

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| 17. Input Parameters: TOC, Alkalinity | | | | | | |
|---|-------------|------------|--------|--------|--|-------|
| R² = 0.810 | | | | | | |
| Adj R² = 0.782 | | | | | | |
| Regression p-value = < 0.001 | | | | | | |
| Log LC50 = 0.220 + (0.843 * logTOC) + (0.507 * log Alkalinity) | | | | | | |
| | Coefficient | Std. Error | t | P | | VIF |
| Constant | 0.22 | 0.248 | 0.888 | 0.389 | | |
| logTOC | 0.843 | 0.159 | 5.292 | <0.001 | | 1.105 |
| log Alkalinity | 0.507 | 0.137 | 3.704 | 0.002 | | 1.105 |
| 18. Input Parameters: DOC, Alkalinity | | | | | | |
| R² = 0.854 | | | | | | |
| Adj R² = 0.833 | | | | | | |
| Regression p-value = < 0.001 | | | | | | |
| Log LC50 = 0.588 + (0.703 * log DOC) + (0.395 * log Alkalinity) | | | | | | |
| | Coefficient | Std. Error | t | P | | VIF |
| Constant | 0.588 | 0.209 | 2.811 | 0.014 | | |
| log DOC | 0.703 | 0.11 | 6.393 | <0.001 | | 1.212 |
| log Alkalinity | 0.395 | 0.125 | 3.152 | 0.007 | | 1.212 |
| 19. Input Parameters: TOC, Alkalinity, pH | | | | | | |
| R² = 0.816 | | | | | | |
| Adj R² = 0.773 | | | | | | |
| Regression p-value = < 0.001 | | | | | | |
| Log LC50 = 0.646 + (0.793 * log TOC) + (0.523 * log Alkalinity) - (0.0511 * pH) | | | | | | |
| | Coefficient | Std. Error | t | P | | VIF |
| Constant | 0.646 | 0.7 | 0.924 | 0.373 | | |
| log TOC | 0.793 | 0.18 | 4.403 | <0.001 | | 1.354 |
| log Alkalinity | 0.523 | 0.142 | 3.685 | 0.003 | | 1.141 |
| pH | -0.0511 | 0.0782 | -0.653 | 0.525 | | 1.226 |
| 20. Input Parameters: DOC, Alkalinity, pH | | | | | | |
| R² = 0.855 | | | | | | |
| Adj R² = 0.822 | | | | | | |
| Regression p-value = < 0.001 | | | | | | |
| Log LC50 = 0.418 + (0.725 * log DOC) + (0.384 * log Alkalinity) + (0.0214 * pH) | | | | | | |
| | Coefficient | Std. Error | t | P | | VIF |
| Constant | 0.418 | 0.632 | 0.662 | 0.52 | | |
| log DOC | 0.725 | 0.136 | 5.312 | <0.001 | | 1.742 |
| log Alkalinity | 0.384 | 0.136 | 2.824 | 0.014 | | 1.329 |
| pH | 0.0214 | 0.0751 | 0.285 | 0.78 | | 1.439 |

TABLE 4
INSTRUCTIONS AND A STEP-BY-STEP EXAMPLE FOR USING THE PROPOSED WER MODEL TO DERIVE AND APPLY SSC TO
STSIU SURFACE WATERS

FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

The following provides step-by-step directions for applying the MLR model to derive site-specific copper criteria. Water chemistry from sample WER-1-1 is provided below and used throughout the calculation as an example.

$$\text{Proposed MLR Model: } \log EC50 = 0.588 + (0.703 * \log DOC) + (0.395 * \log Alkalinity)$$

Sample WER-1-1 water chemistry (select parameters required for MLR-model application):

DOC = 10.7
 Alkalinity = 74
 Hardness = 90

Step 1: Input a sample's measured water chemistry values into the MLR-model equation to calculate a predicted Site water copper EC50 value:

$$\log EC50 = 0.588 + (0.703 * \log DOC) + (0.395 * \log Alkalinity)$$

$$\text{Predicted EC50} = 10^{(0.588 + (0.703 \times \log 10.7) + (0.395 \times \log 74))}$$

$$\text{Predicted EC50} = 112.203$$

Step 2: Normalize the predicted Site water EC50 to a standard hardness using the copper-criteria hardness slope:

$$EC50_{\text{hardness normalized}} = EC50_{\text{at sample hardness}} \times \left(\frac{\text{Standard Hardness}}{\text{Sample Hardness}} \right)^{0.9422}$$

$$EC50_{\text{hardness normalized}} = 112.203 \times \left(\frac{100}{90} \right)^{0.9422}$$

$$EC50_{\text{hardness normalized}} = 123.91$$

Step 3: Divide the normalized predicted Site EC50 by the hardness-normalized *D. magna* SMAV for copper to calculate a sample WER:

$$\text{Sample WER} = \frac{\text{Site Water } EC50_{\text{hardness normalized}}}{D. magna SMAV_{\text{hardness normalized}}}$$

$$\text{Sample WER} = \frac{123.91}{19.31}$$

$$\text{Sample WER} = 6.417$$

Step 4: Multiply the sample WER by the hardness-based standard to derive a site-specific standard:

$$\text{Sample site specific Cu CMC} = \text{WER} \times \text{Hardness Based Standard}$$

$$\text{Sample site specific Cu CMC} = 6.417 \times 12.169$$

$$\text{Sample site specific Cu CMC} = 78.088 \frac{\mu\text{g}}{\text{L}} \text{ dissolved Cu}$$

Figures



LEGEND:

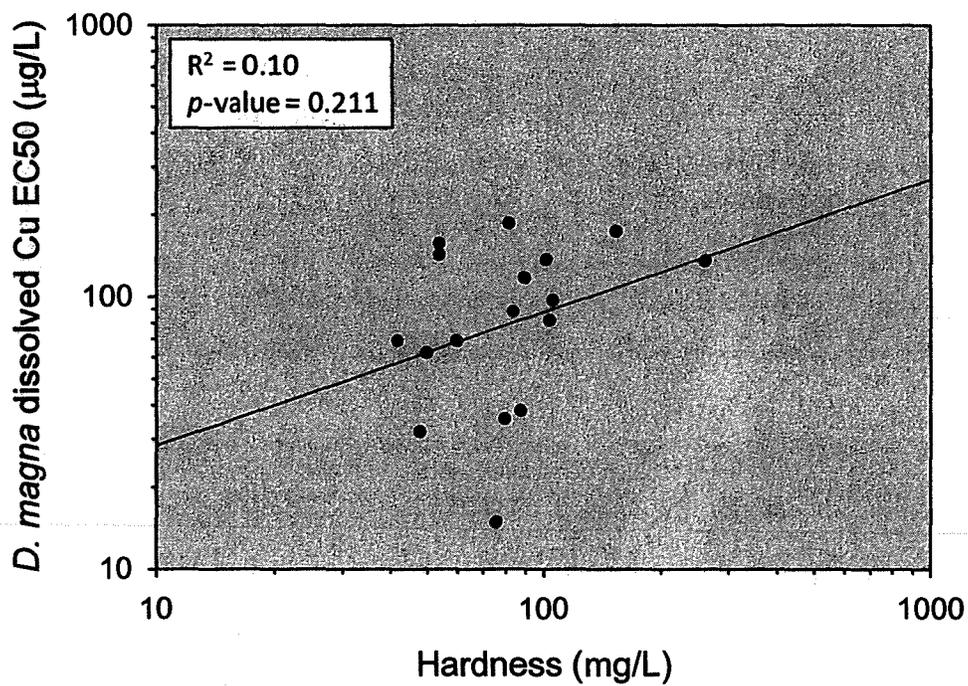
- Analytical Sample Only
- Tox and Analytical Sample
- ★ Tox and Analytical Sample (Sampled Twice)
- STSIU Study Boundary
- City Areas
- Drainages
- Lampbright Subwatershed Boundaries
- Lampbright Subwatersheds within AOC
- Hanover-Whitwater Subwatershed Boundaries
- Hanover-Whitwater Subwatersheds within AOC
- Stockpiles
- Highway
- Railroad
- Town Roads



FREEMPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

WER SAMPLE LOCATIONS

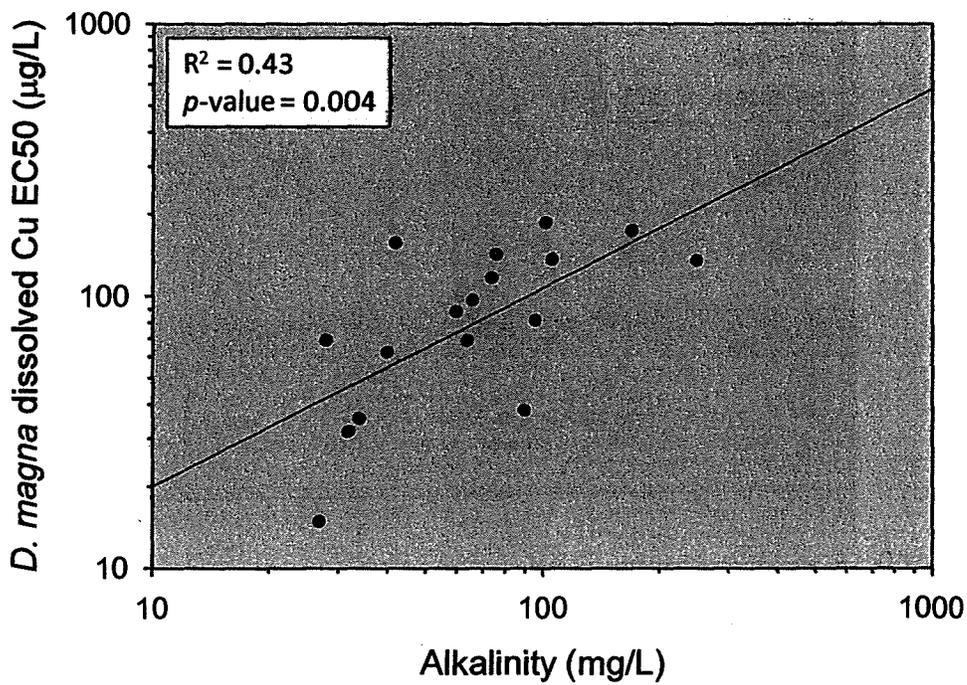
ARCADIS | FIGURE 1



Notes:

R^2 = Coefficient of determination
 p -value = Statistical level of significance
 Toxicity and chemistry data were log-transformed
 for regression analysis

| | |
|--|--------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| REGRESSION OF HARDNESS COMPARED TO MEASURED DISSOLVED COPPER EC50 VALUES | |
| | FIGURE 2 |



Notes:

R^2 = Coefficient of determination

p -value = Statistical level of significance

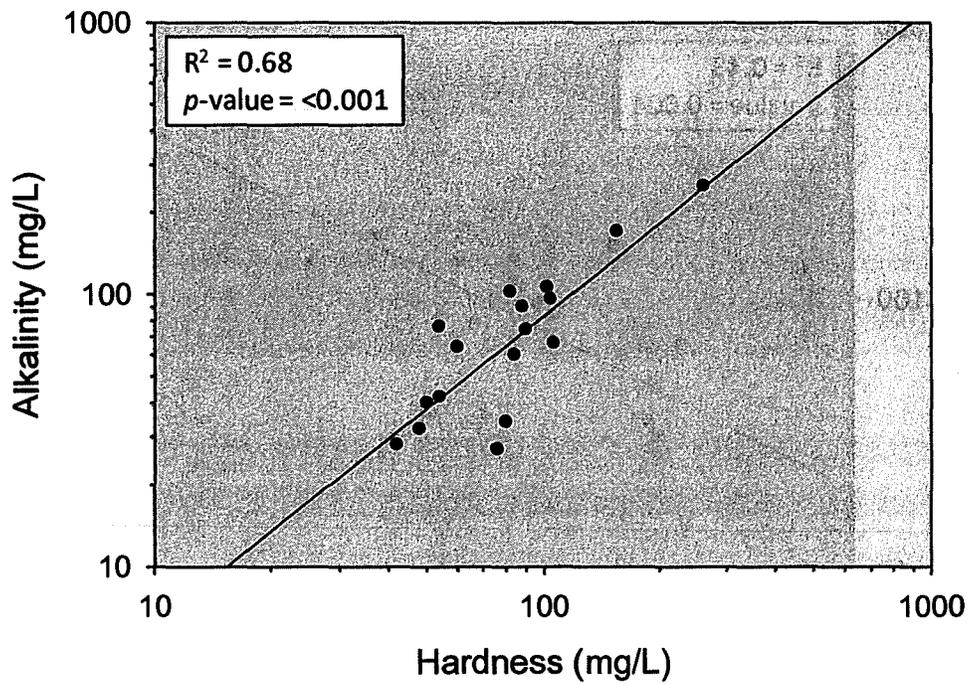
Toxicity and chemistry data were log-transformed for regression analysis

FREEPORT-MCMORAN CHINOMINES COMPANY
 VANADIUM, NEW MEXICO
**SITE-SPECIFIC COPPER TOXICITY MODEL
 REPORT**

REGRESSION OF ALKALINITY COMPARED TO
 MEASURED DISSOLVED COPPER EC50 VALUES



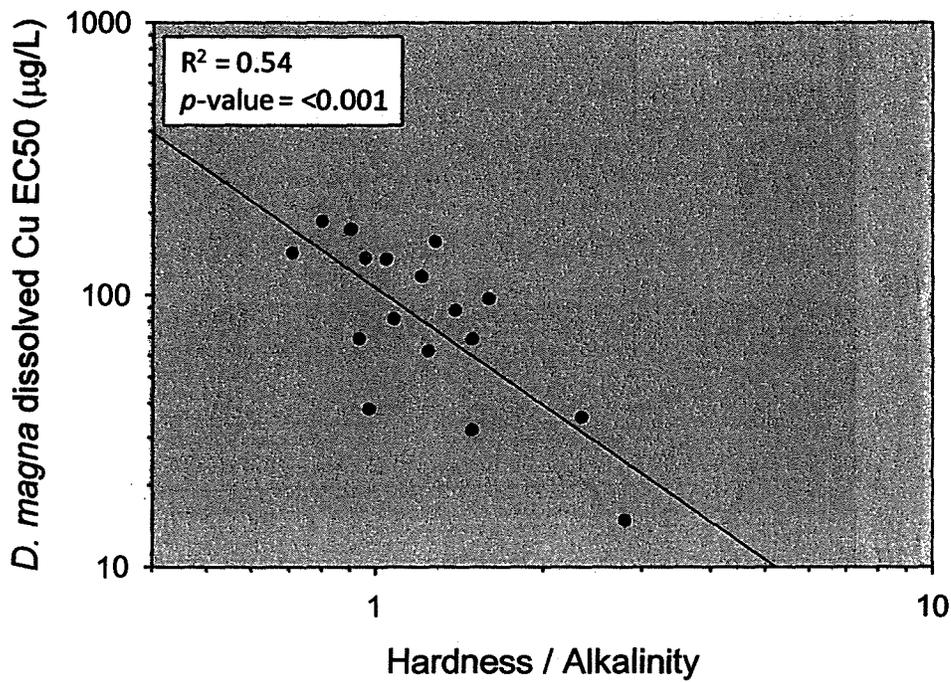
FIGURE
3



Notes:

R^2 = Coefficient of determination
 p -value = Statistical level of significance
 Chemistry data were log-transformed
 for regression analysis

| | |
|--|------------------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| REGRESSION OF ALKALINITY COMPARED TO HARDNESS | |
|  | FIGURE 4 |



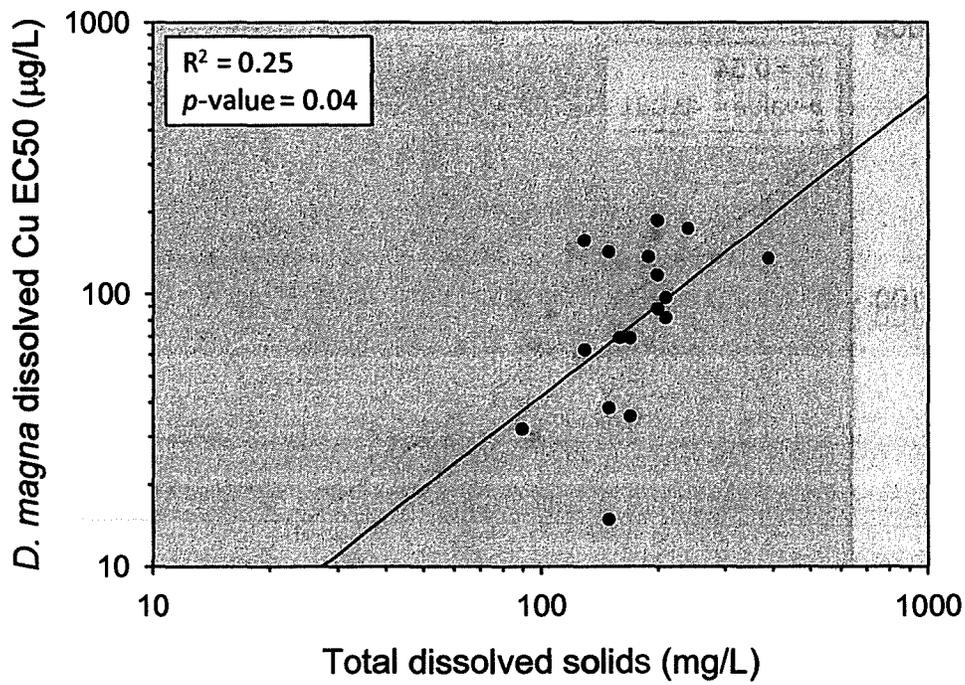
Notes:

R^2 = Coefficient of determination

p -value = Statistical level of significance

Toxicity and chemistry data were log-transformed for regression analysis

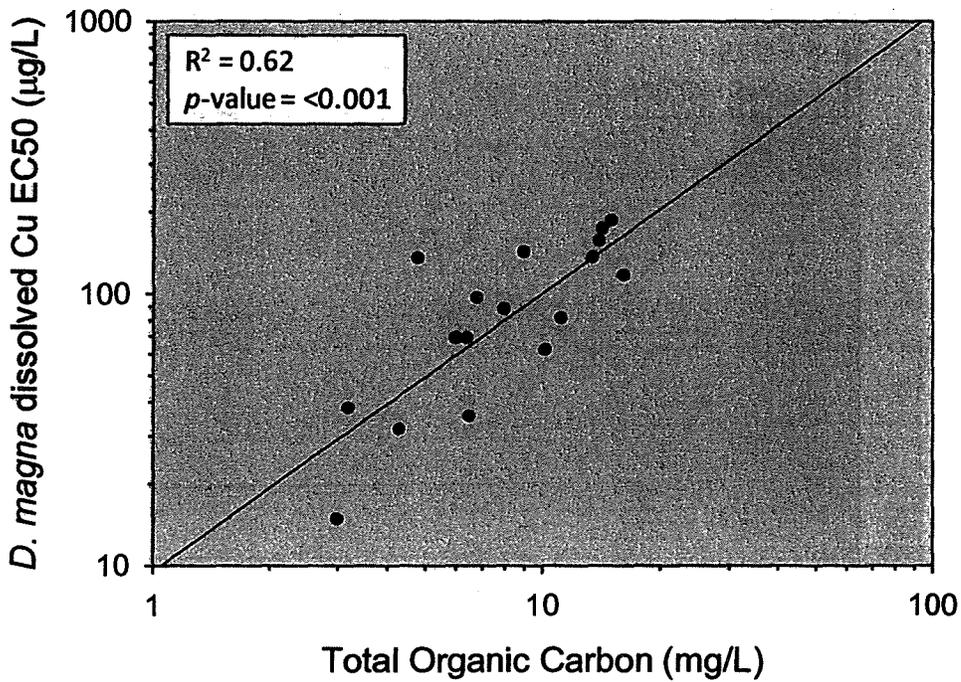
| | |
|--|--------------------|
| FREEPORT-MCMORAN CHINOMNES COMPANY VANADIUM, NEW MEXICO SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| REGRESSION OF HARDNESS/ALKALINITY COMPARED TO MEASURED DISSOLVED COPPER EC50 VALUES | |
|  | FIGURE 5 |



Notes:

R^2 = Coefficient of determination
 p -value = Statistical level of significance
 Toxicity and chemistry data were log-transformed
 for regression analysis

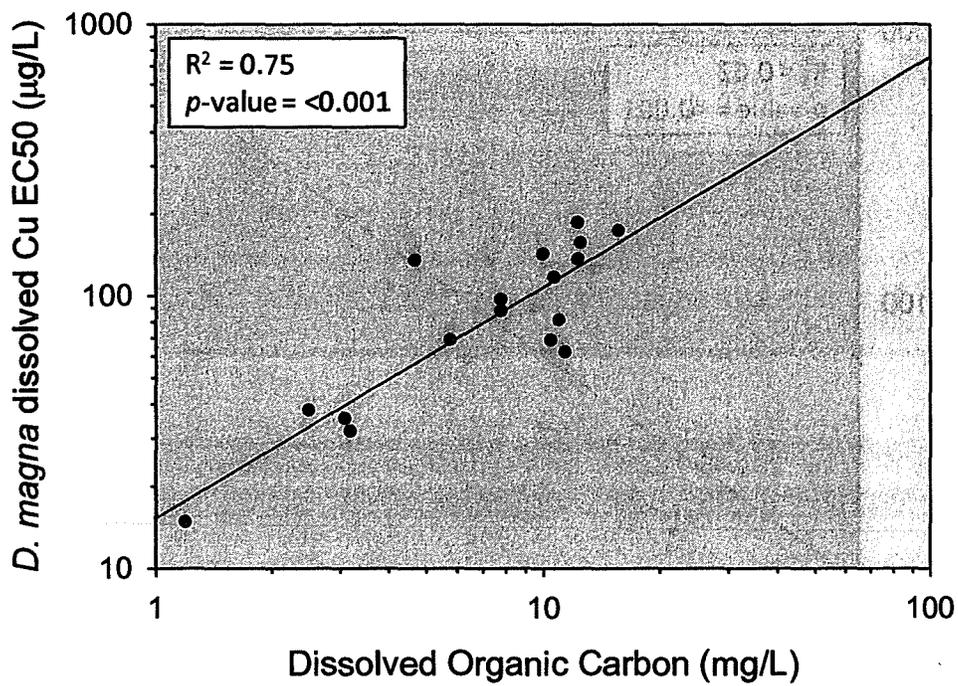
| | |
|--|--------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| REGRESSION OF TDS COMPARED TO MEASURED DISSOLVED COPPER EC50 VALUES | |
|  | FIGURE 6 |



Notes:

R^2 = Coefficient of determination
 p -value = Statistical level of significance
 Toxicity and chemistry data were log-transformed
 for regression analysis

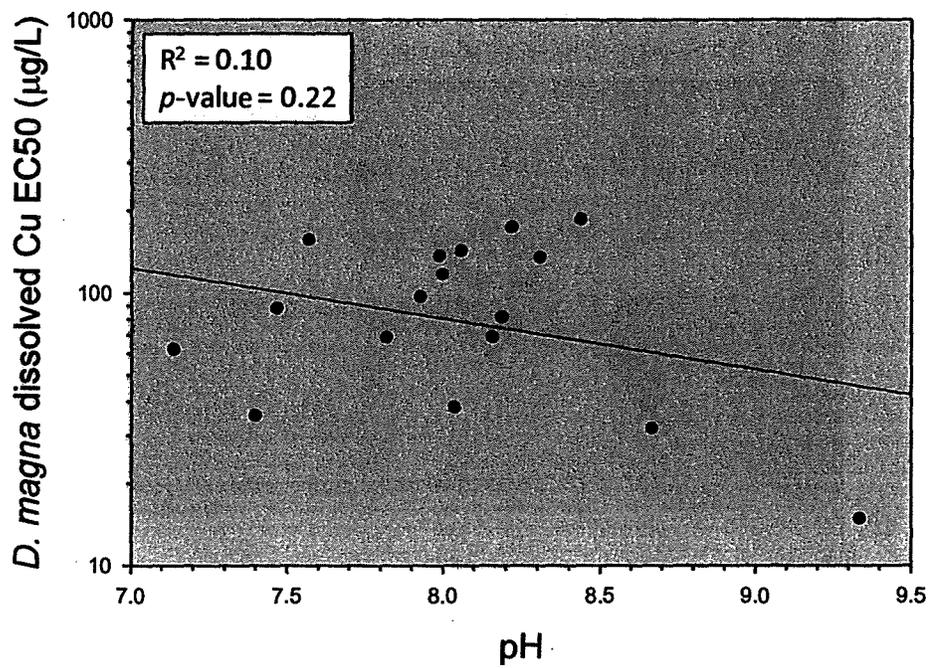
| | |
|---|--------------------|
| FREEPORT-MCMORAN CHINOMINES COMPANY VANADIUM, NEW MEXICO SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| REGRESSION OF TOC COMPARED TO MEASURED DISSOLVED COPPER EC50 VALUES | |
|  | FIGURE 7 |



Notes:

R^2 = Coefficient of determination
 p -value = Statistical level of significance
 Toxicity and chemistry data were log-transformed
 for regression analysis

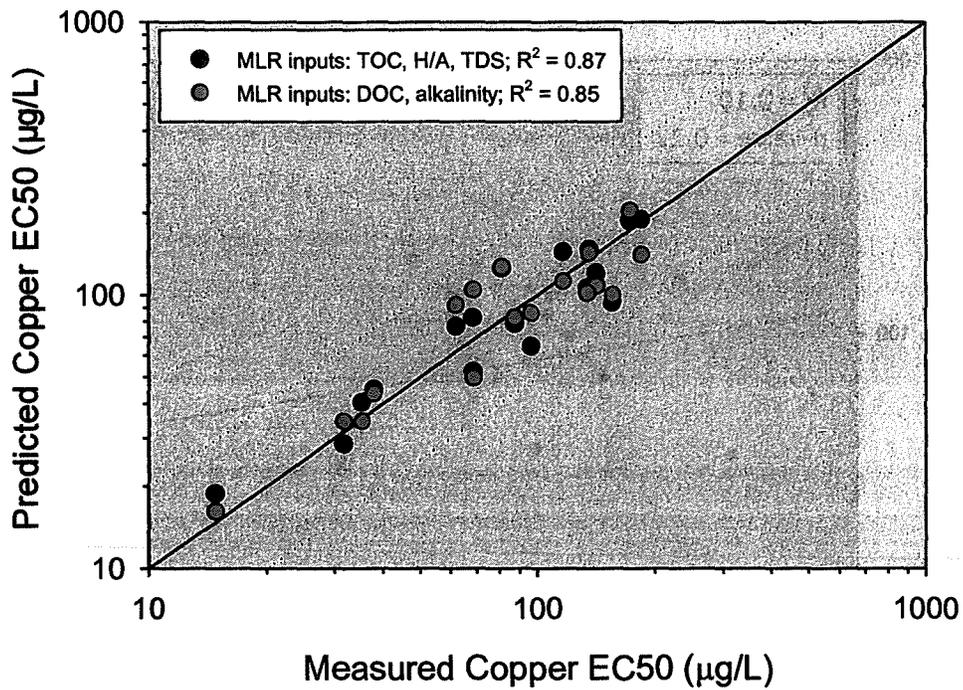
| | |
|--|--------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| REGRESSION OF DOC COMPARED TO MEASURED DISSOLVED COPPER EC50 VALUES | |
|  | FIGURE 8 |



Notes:

R^2 = Coefficient of determination
 p -value = Statistical level of significance
 Toxicity data were log-transformed
 for regression analysis

| | |
|--|--------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| REGRESSION OF pH COMPARED TO MEASURED DISSOLVED COPPER EC50 VALUES | |
| | FIGURE 9 |



Notes:

R^2 = Coefficient of determination (for predicted vs. measured EC50 comparison)

p -value = Statistical level of significance

Predicted and measured EC50 values were log-transformed for regression analysis

Solid diagonal line = predicted EC50 equals measured EC50

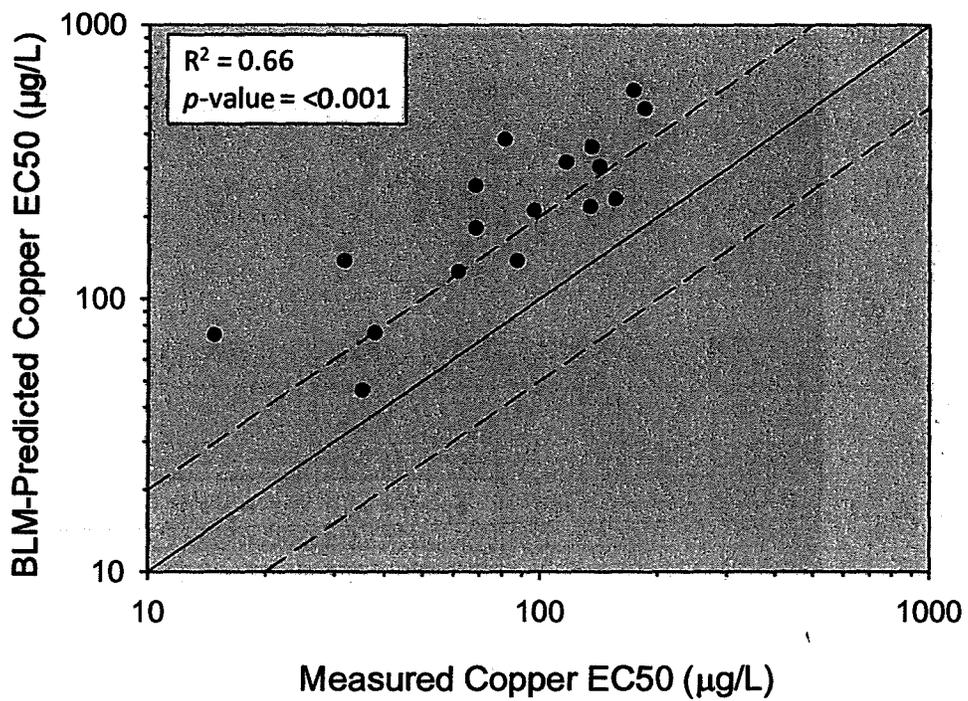
Dashed diagonal lines = ± 2 -fold measured versus predicted

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SITE-SPECIFIC COPPER TOXICITY MODEL
REPORT

MLR MODEL-PREDICTED DISSOLVED COPPER
EC50 VALUES COMPARED TO MEASURED
DISSOLVED COPPER EC50 VALUES

 **ARCADIS**

FIGURE
10



Notes:

R^2 = Coefficient of determination

p -value = Statistical level of significance

Predicted and measured EC50 values were log-transformed for regression analysis

Solid diagonal line = predicted EC50 equals measured EC50

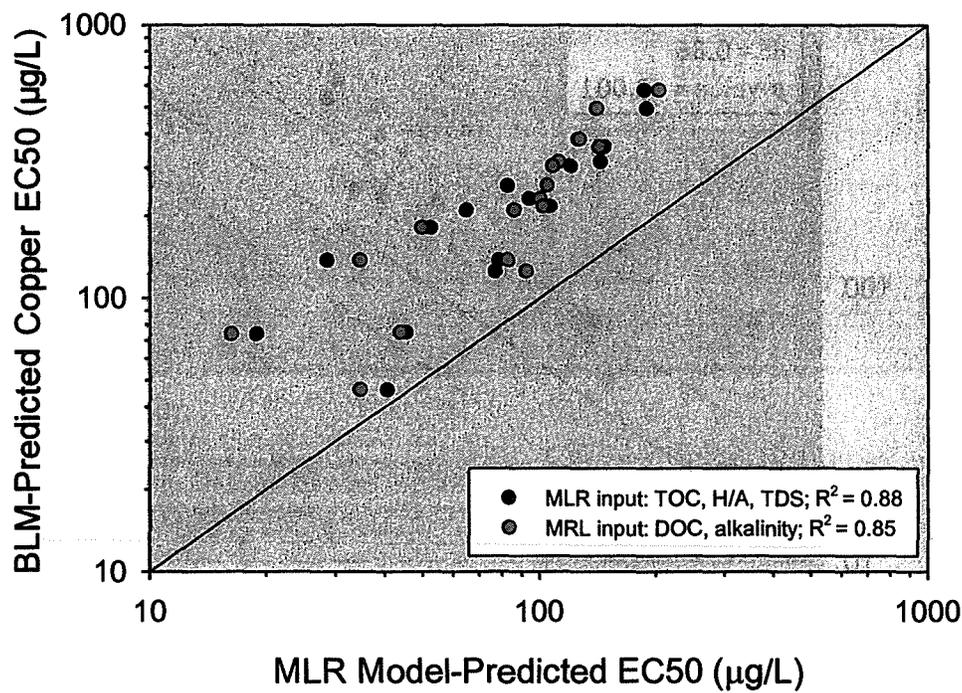
Dashed diagonal lines = ± 2 -fold measured versus predicted

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SITE-SPECIFIC COPPER TOXICITY MODEL
REPORT

BLM-PREDICTED DISSOLVED COPPER EC50
VALUES COMPARED TO MEASURED
DISSOLVED COPPER EC50 VALUES



FIGURE
11



Notes:

R^2 = Coefficient of determination

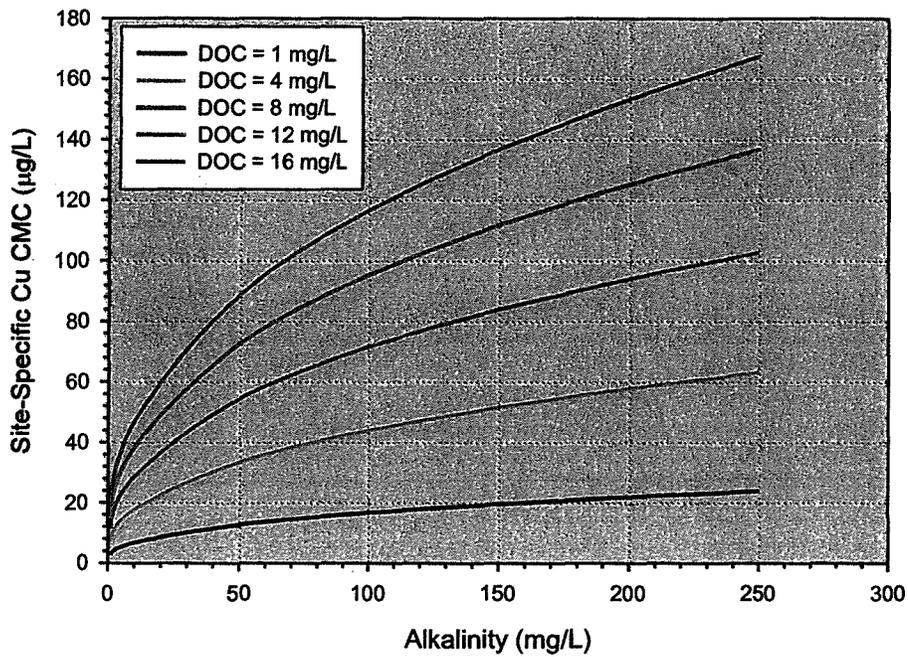
p -value = Statistical level of significance

Predicted EC50 values were log-transformed
for regression analysis

Solid diagonal line = BLM predicted EC50 equals MLR-model-predicted EC50

Dashed diagonal lines = ± 2 -fold BLM -predicted versus MLR mode predicted

| | |
|---|---------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| BLM-PREDICTED DISSOLVED COPPER EC50 VALUES COMPARED TO MLR MODEL- PREDICTED DISSOLVED COPPER EC50 VALUES | |
| | FIGURE 12 |



Notes:

CMC = Criteria Maximum Concentrations
 Example Site-specific CMC values calculated at a hardness of 100 mg/L.

| | |
|--|---------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| EXAMPLE OF SITE-SPECIFIC COPPER CMC CALCULATED USING THE PROPOSED WER MODEL APPROACH OVER AN ALKALINITY AND DOC RANGE | |
| | FIGURE 13 |

Appendix A

**Data Tables Presented
in the Criteria
Adjustment Interim
Report (ARCADIS
2013a)**

**APPENDIX A: TABLE 1
SUMMARY OF ALL SURFACE WATER SAMPLING LOCATIONS**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IN-SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Sample ID | Drainage Description | Longitude | Latitude | Maximum Length (m) | Maximum Width (m) | Maximum Depth (m) | Temperature (°C) | Conductivity (mS/cm) | Dissolved Oxygen (mg/L) | pH |
|--|----------------------|-------------|-----------|--------------------|-------------------|-------------------|------------------|----------------------|-------------------------|------|
| Round 1 WER Toxicity Samples | | | | | | | | | | |
| WER-1-1 | Lucky Bill | -108.09669 | 32.76198 | 15 | 10 | 0.61 | 29.47 | 0.261 | -- | 7.08 |
| WER-1-2 | Lucky Bill | -108.093141 | 32.759732 | 20 | 10 | 0.23 | 22.38 | 0.258 | -- | 6.33 |
| WER-1-5 | C-Drainage | -108.101616 | 32.696746 | 50 | 4 | 0.24 | 31.67 | 0.205 | -- | 6.88 |
| WER-1-6 | C-Drainage | -108.0899 | 32.7227 | 8.5 | 1.5 | 0.24 | 23.13 | 0.158 | -- | 6.42 |
| WER-1-7 | B-Drainage | -108.06822 | 32.6879 | 2.5 | 1.6 | 0.55 | 20.94 | 0.256 | -- | 7.18 |
| WER-1-9 | Lower Martin | -108.0479 | 32.6992 | 65 | 7 | 0.52 | 21.29 | 0.197 | -- | 7.5 |
| WER-1-10 | Mid Martin | -108.056804 | 32.728667 | 15 | 3.9 | 0.18 | 21.84 | 0.552 | -- | 7.38 |
| WER-1-11 | G-Drainage | -108.026981 | 32.730613 | 9.4 | 4.4 | 0.61 | 25.47 | 0.337 | -- | 6.37 |
| WER-1-12 | Rustler | -108.012367 | 32.742963 | 32.8 | 5 | 0.82 | 22.17 | 0.215 | -- | 6.09 |
| WER-1-RCS-1 | Rustler, south fork | -108.026718 | 32.74311 | 10 | 10 | 4.5 | 22.85 | 0.127 | -- | 8.67 |
| WER-1-D1-2 | D1-Drainage | -108.116935 | 32.748954 | 5.5 | 2.5 | 0.49 | 17.92 | 0.182 | -- | 7.41 |
| WER-1-D2-1 | D2-Drainage | -108.112792 | 32.719935 | 3 | 3 | 0.73 | 22.1 | 0.164 | -- | 6.62 |
| Round 1 Additional Analytical Samples | | | | | | | | | | |
| WER-1-D1 | D1-Drainage | -108.10912 | 32.7514 | 8.7 | 4.6 | 0.09 | 17.04 | 0.129 | -- | 7.7 |
| WER-D2-2 | D2-Drainage | -108.11544 | 32.7185 | 2 | 1 | 0.15 | 19.89 | 0.206 | -- | 7.01 |
| WER-1-BD | C-Drainage | -108.09444 | 32.6939 | 2 | 0.5 | 0.40 | 29.72 | 0.174 | -- | 7.42 |
| WER-MC-1 | Martin Canyon | -108.05569 | 32.7085 | 30 | 3 | 0.15 | 28.69 | 0.247 | -- | 7.47 |
| WER-1-RCS2 | Rustler Canyon | -108.02677 | 32.7429 | 7.5 | 2.5 | 0.30 | 21.52 | 0.117 | -- | 7.34 |
| WER-1-RCS-3 | Rustler Canyon | -108.01934 | 32.7456 | 10 | 2.5 | 0.46 | 21.22 | -0.194 | -- | 6.15 |
| Round 2 WER Toxicity Samples | | | | | | | | | | |
| WER-2-1 | Lucky Bill | -108.09669 | 32.76198 | 10 | 8.5 | 0.61 | 20.48 | 0.291 | 8.75 | 7.54 |
| WER-2-6 | C-Drainage | -108.0899 | 32.7227 | 8 | 1.5 | 0.25 | 16.76 | 0.144 | 5 | 6.94 |
| WER-2-9 | Lower Martin | -108.0479 | 32.6992 | 21.88 | 4.75 | 0.67 | 20.58 | 0.232 | 7.61 | 8.45 |
| WER-2-11 | G-Drainage | -108.026981 | 32.730613 | 7.5 | 3.5 | 0.76 | 20.49 | 0.282 | 7.48 | 7.61 |
| WER-2-12 | Rustler | -108.012367 | 32.742963 | 6.37 | 1.82 | 0.30 | 13.98 | 0.226 | 8.03 | 7.29 |
| WER-2-D1-2 | D1-Drainage | -108.116935 | 32.748954 | 3 | 4.4 | 0.43 | 13.81 | 0.205 | 7.63 | 7.47 |

Notes:

- Sample ID nomenclature: Sample type - Sample round - Sample #.
 - Post-calibration of DO for first round of sampling did not meet calibration performance criteria.
- m = meters.
°C = degrees celsius.
mS/cm = millisiemens per cm.
mg/L = milligrams per liter.

**APPENDIX A: TABLE 2
SUMMARY OF ANALYTICAL CHEMISTRY METHODS**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Constituent | Method | MDL (mg/L) | Sample Holding Time | Preservation |
|-----------------------------------|-------------------------|-------------|---------------------|----------------------------------|
| Metals, dissolved | | | | |
| Aluminum, dissolved | M 200.8 ICP-MS | 0.001 | 180-d | HNO ₃ to pH <2 |
| Cadmium, dissolved | M 200.8 ICP-MS | 0.0001 | 180-d | HNO ₃ to pH <2 |
| Calcium, dissolved | M 200.7 ICP | 0.2 | 180-d | HNO ₃ to pH <2 |
| Copper, dissolved | M 200.8 ICP-MS | 0.0005 | 180-d | HNO ₃ to pH <2 |
| Iron, dissolved | M 200.7 ICP | 0.02 | 180-d | HNO ₃ to pH <2 |
| Lead, dissolved | M 200.8 ICP-MS | 0.0001 | 180-d | HNO ₃ to pH <2 |
| Magnesium, dissolved | M 200.7 ICP | 0.2 | 180-d | HNO ₃ to pH <2 |
| Manganese, dissolved | M 200.7 ICP-MS | 0.0005 | 180-d | HNO ₃ to pH <2 |
| Potassium, dissolved | M 200.7 ICP | 0.3 | 180-d | HNO ₃ to pH <2 |
| Sodium, dissolved | M 200.7 ICP | 0.3 | 180-d | HNO ₃ to pH <2 |
| Zinc, dissolved | M 200.8 ICP-MS | 0.002 | 180-d | HNO ₃ to pH <2 |
| Metals, total recoverable | | | | |
| Aluminum, total | M 200.8 ICP-MS | 0.001 | 180-d | HNO ₃ to pH <2 |
| Cadmium, total | M 200.8 ICP-MS | 0.0001 | 180-d | HNO ₃ to pH <2 |
| Calcium, total | M 200.7 ICP | 0.2 | 180-d | HNO ₃ to pH <2 |
| Copper, total | M 200.8 ICP-MS | 0.0005 | 180-d | HNO ₃ to pH <2 |
| Iron, total | M 200.7 ICP | 0.02 | 180-d | HNO ₃ to pH <3 |
| Lead, total | M 200.8 ICP-MS | 0.0001 | 180-d | HNO ₃ to pH <2 |
| Magnesium, total | M 200.7 ICP | 0.2 | 180-d | HNO ₃ to pH <2 |
| Manganese, total | M 200.8 ICP-MS | 0.0005 | 180-d | HNO ₃ to pH <3 |
| Zinc, total | M 200.8 ICP-MS | 0.002 | 180-d | HNO ₃ to pH <2 |
| Water Quality parameters | | | | |
| Alkalinity as CaCO ₃ | SM2320B -Titration | 2 | 14-d | ≤ 6 degree C |
| Carbon, dissolved organic (DOC) | SM5310B | 1 | 28-d | Sulfuric acid, cool (4 degree C) |
| Carbon, total organic (TOC) | SM5310B | 1 | 28-d | Sulfuric acid, cool (4 degree C) |
| Cation-Anion balance | Calculation | Calculation | -- | -- |
| Chloride | SM4500CL-E | 1 | 28-d | ≤ 6 degree C |
| Hardness as CaCO ₃ | SM2340B-Calculation | Calculation | -- | -- |
| Residue, Filterable (TDS) @ 180 C | SM2540C | 10 | -- | ≤ 6 degree C |
| Sulfate | D516-02 - Turbidimetric | 5 | 28-d | ≤ 6 degree C |
| TDS (calculated) | Calculation | Calculation | -- | -- |
| TDS (ratio-measured/calculated) | Calculation | Calculation | -- | -- |
| pH | YSI data sonde | -- | -- | -- |
| Temperature | YSI data sonde | -- | -- | -- |
| Dissolved Oxygen | YSI data sonde | -- | -- | -- |
| Conductivity | YSI data sonde | -- | -- | -- |

Notes:

*Extended sample hold time may be required for some WER samples.

TDS = Total dissolved solids.

-- Not pertinent to this field.

mg/L = milligrams per liter.

**APPENDIX A: TABLE 3
EXPERIMENTAL CONDITIONS USED IN WER TOXICITY TESTS CONDUCTED WITH *DAPHNIA MAGNA* AND *PIMEPHALES PROMELAS***

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Parameters | <i>Daphnia magna</i> | <i>Pimephales promelas</i> |
|-----------------------------------|---|---|
| Method | EPA-821-R-02-012 | EPA-821-R-02-012 |
| Test Duration | 48 hours | 96 hours |
| Sample Collection Procedure | Grab | Grab |
| Dilution Water | N/A | N/A |
| Acclimation | Cultured in moderately hard reconstituted water | Cultured in moderately hard reconstituted water |
| Age of Organisms at Start | <24 hr. old | 7 day old |
| Feeding | None | Before 48 hr. solution renewal |
| Endpoint | Mortality | Mortality |
| Type of Exposure Chamber | 30 mL disposable plastic cup | 9 oz disposable plastic cup |
| Volume of Exposed Chamber | 25 mL | 250 mL |
| Number of Animals Exposed/Chamber | 5 | 10 |
| Number of Replicates/Treatment | 4 | 2 in round 1; 4 in round 2 |
| Test Temperature | 20.0 deg C +/- 1.0 deg C | 20.0 deg C +/- 1.0 deg C |

**APPENDIX A: TABLE 4
TIMELINE OF SURFACE WATER SAMPLES USED IN WER TOXICITY TESTS**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Sample ID | Sample Collection Date and Time | Lab Received Date and Time | Screening Level Start Date and Time | Screening Level End Date and Time | Definitive Test Start Date and Time | Definitive Test End Date and Time | Species | Hours Between Sample Collection and Start of Definitive Test |
|------------------------|---------------------------------|----------------------------|-------------------------------------|-----------------------------------|-------------------------------------|-----------------------------------|----------------------------|--|
| Round 1 Samples | | | | | | | | |
| WER 1-1 | 8/29/11 13:50 | 8/30/11 10:00 | 8/31/11 9:55 | 9/1/11 9:55 | 9/2/11 11:55 | 9/4/11 12:25 | <i>Daphnia magna</i> | 94 |
| WER 1-1 | 8/29/11 13:50 | 8/30/11 10:00 | 8/31/11 10:30 | 9/1/11 10:30 | 9/2/11 11:30 | 9/6/11 11:10 | <i>Pimephales promelas</i> | 94 |
| WER 1-2 | 8/29/11 14:45 | 8/30/11 10:00 | 8/31/11 10:00 | 9/1/11 10:00 | 9/2/11 11:35 | 9/4/11 11:20 | <i>Daphnia magna</i> | 92.8 |
| WER 1-5 | 8/31/11 12:55 | 9/1/11 9:30 | 9/2/11 11:20 | 9/3/11 11:20 | 9/4/11 13:30 | 9/6/11 13:05 | <i>Daphnia magna</i> | 96.5 |
| WER 1-6 | 9/1/11 13:00 | 9/2/11 9:30 | 9/3/11 10:35 | 9/4/11 10:35 | 9/5/11 14:45 | 9/7/11 14:50 | <i>Daphnia magna</i> | 97.7 |
| WER 1-7 | 8/31/11 10:15 | 9/1/11 9:30 | 9/2/11 11:25 | 9/3/11 11:25 | 9/4/11 13:45 | 9/6/11 13:25 | <i>Daphnia magna</i> | 99.5 |
| WER 1-9 | 8/30/11 9:45 | 8/31/11 9:25 | 9/1/11 10:30 | 9/2/11 10:30 | 9/3/11 11:50 | 9/5/11 12:40 | <i>Daphnia magna</i> | 98 |
| WER 1-10 | 8/30/11 10:55 | 8/31/11 9:25 | 9/1/11 10:45 | 9/2/11 10:45 | 9/3/11 11:40 | 9/5/11 11:50 | <i>Daphnia magna</i> | 96.8 |
| WER 1-11 | 8/30/11 11:40 | 8/31/11 9:25 | 9/1/11 11:00 | 9/2/11 11:00 | 9/3/11 12:10 | 9/5/11 12:50 | <i>Daphnia magna</i> | 96.5 |
| WER 1-12 | 9/2/11 9:05 | 9/3/11 8:45 | 9/4/11 10:15 | 9/5/11 10:15 | 9/6/11 15:00 | 9/8/11 15:40 | <i>Daphnia magna</i> | 102 |
| WER 1-RCS | 9/2/11 11:00 | 9/3/11 8:45 | 9/4/11 10:20 | 9/5/11 10:20 | 9/6/11 15:15 | 9/8/11 16:15 | <i>Daphnia magna</i> | 100 |
| WER D1-2 | 9/1/11 9:05 | 9/2/11 9:30 | 9/3/11 10:20 | 9/4/11 10:20 | 9/5/11 14:15 | 9/7/11 14:10 | <i>Daphnia magna</i> | 101 |
| WER D2-1 | 9/1/11 10:30 | 9/2/11 9:30 | 9/3/11 10:25 | 9/4/11 10:25 | 9/5/11 14:30 | 9/7/11 14:30 | <i>Daphnia magna</i> | 100 |
| Round 2 Samples | | | | | | | | |
| WER 2-1 | 9/19/11 13:20 | 9/20/11 9:30 | 9/21/11 10:35 | 9/22/11 10:15 | 9/23/11 9:50 | 9/25/11 9:30 | <i>Daphnia magna</i> | 92.5 |
| WER 2-1 | 9/19/11 13:20 | 9/20/11 9:30 | 9/21/11 11:25 | 9/22/11 11:25 | 9/23/11 10:15 | 9/27/11 9:45 | <i>Pimephales promelas</i> | 93 |
| WER 2-6 | 9/19/11 9:45 | 9/20/11 9:30 | 9/21/11 11:05 | 9/22/11 10:50 | 9/23/11 16:45 | 9/25/11 16:15 | <i>Daphnia magna</i> | 103 |
| WER 2-9 | 9/20/11 12:00 | 9/21/11 9:30 | 9/22/11 10:45 | 9/23/11 11:00 | 9/24/11 12:40 | 9/26/11 11:45 | <i>Daphnia magna</i> | 96.7 |
| WER 2-11 | 9/20/11 12:45 | 9/21/11 9:30 | 9/22/11 10:50 | 9/23/11 11:10 | 9/24/11 12:15 | 9/26/11 11:25 | <i>Daphnia magna</i> | 95.5 |
| WER 2-12 | 9/20/11 9:15 | 9/21/11 9:30 | 9/22/11 11:00 | 9/23/11 11:15 | 9/24/11 11:55 | 9/26/11 11:10 | <i>Daphnia magna</i> | 98.7 |
| WER 2-D1-2 | 9/19/11 11:40 | 9/20/11 9:30 | 9/21/11 10:50 | 9/22/11 10:35 | 9/23/11 17:00 | 9/25/11 16:25 | <i>Daphnia magna</i> | 101 |

APPENDIX A: TABLE 5
WATER-CHEMISTRY PARAMETERS IN LABORATORY DILUTION WATERS USED IN WER TOXICITY TESTS, MEASURED BY GEI LABORATORY

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Control ID | Analysis Temperature °C | Total Hardness (mg CaCO ₃ /L) | pH | Alkalinity (mg CaCO ₃ /L) | Conductivity (mS/cm) | Dissolved Oxygen (mg/L) | Total Dissolved Solids (mg/L) | Total Suspended Solids (mg/L) | Total Organic Carbon (mg/L) |
|-------------------------|-------------------------|--|------|--------------------------------------|----------------------|-------------------------|-------------------------------|-------------------------------|-----------------------------|
| Round 1 Controls | | | | | | | | | |
| A-80 | 20 | 80 | 8.2 | 58 | 0.293 | 7 | 144 | <5 | 3.81 |
| B-80 | 20 | 78 | 8.24 | 22 | 0.291 | 7.2 | 143 | <5 | 3.81 |
| B-150 | 20 | 168 | 8.57 | 112 | 0.547 | 7.2 | 268 | <5 | 1.16 |
| C-50 | 20 | 50 | 7.98 | 36 | 0.187 | 7.1 | 92 | <5 | 3.11 |
| C-100 | 20 | 98 | 8.31 | 66 | 0.343 | 7.2 | 168 | <5 | 2.62 |
| D-44 | 20 | 46 | 7.87 | 32 | 0.174 | 7.1 | 85 | <5 | 1.86 |
| E-40 | 20 | 42 | 7.71 | 30 | 0.169 | 7.9 | 82 | <5 | 1.86 |
| E-70 | 20 | 72 | 7.85 | 48 | 0.265 | 8.6 | 130 | <5 | — |
| Round 2 Controls | | | | | | | | | |
| A2-45 | 20 | 42 | 7.3 | 32 | 0.159 | 7.5 | 78 | — | 0.97 |
| A2-100 | 20 | 96 | 8.13 | 70 | 0.346 | 7.9 | 170 | — | 0.683 |
| B2-75 | 20 | 72 | 7.65 | 52 | 0.269 | 7.2 | 132 | — | — |
| B2-110 | 20 | 100 | 8.02 | 72 | 0.409 | 7.3 | 200 | — | 0.85 |

Notes:

1. Due to a GEI Technician error, TOC results from round 1 laboratory dilution water tests exceeded hold times.

°C = degrees celsius.

< values - the material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantification limit or the sample detection limit.

mg CaCO₃/L = milligrams calcium carbonate per liter.

mS/cm = millisiemens per centimeter.

mg/L = milligrams per liter.

**APPENDIX A: TABLE 6
WATER-CHEMISTRY PARAMETERS IN LABORATORY DILUTION WATERS USED IN WER TOXICITY
TESTS, MEASURED BY AN EXTERNAL ANALYTICAL LABORATORY (ACZ)**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Parameters | A-50 | B-150 | C-50 | C-100 | D-44 | E-40 | E-70 |
|---|------|-------|------|-------|------|------|------|
| Major Cations (mg/L) | | | | | | | |
| Calcium, dissolved | 13.2 | 26.2 | 7.8 | 14.9 | 7 | 6.5 | 10.9 |
| Calcium, total | -- | 27.7 | -- | -- | -- | 6.9 | -- |
| Magnesium, dissolved | 11.5 | 22.9 | 6.8 | 13 | 6.2 | 5.8 | 9.6 |
| Magnesium, total | -- | 24.4 | -- | -- | -- | 6 | -- |
| Potassium, dissolved | 1.3 | 2.3 | 1.2 | 2.2 | 1 | 1.1 | 1.6 |
| Sodium, dissolved | 26.3 | 51.5 | 15.9 | 30.1 | 14.1 | 13 | 21.7 |
| Metals (µg/L) | | | | | | | |
| Aluminum, dissolved | -- | <1 | -- | -- | -- | <1 | -- |
| Aluminum, total | -- | 3 | -- | -- | -- | 7 | -- |
| Cadmium, dissolved | -- | <0.1 | -- | -- | -- | <0.1 | -- |
| Cadmium, total | -- | <0.1 | -- | -- | -- | <0.1 | -- |
| Copper, dissolved | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Copper, total | <0.5 | <0.5 | <0.5 | <1 | <0.5 | <0.5 | <0.5 |
| Iron, dissolved | -- | <20 | -- | -- | -- | <20 | -- |
| Iron, total | -- | <20 | -- | -- | -- | <20 | -- |
| Lead, dissolved | -- | <0.1 | -- | -- | -- | <0.1 | -- |
| Lead, total | -- | <0.1 | -- | -- | -- | <0.1 | -- |
| Manganese, dissolved | <0.5 | <0.5 | <0.5 | <0.5 | 0.7 | <0.5 | <0.5 |
| Manganese, total | -- | <0.5 | -- | -- | -- | <0.5 | -- |
| Zinc, dissolved | -- | 3 | -- | -- | -- | 59 | -- |
| Zinc, total | -- | 4 | -- | -- | -- | <2 | -- |
| Wet Chemistry | | | | | | | |
| Bicarbonate as CaCO ₃ (mg/L) | 54 | 106 | 34 | 66 | 32 | 29 | 47 |
| Dissolved inorganic carbon (mg/L) | -- | -- | -- | -- | -- | -- | -- |
| Dissolved organic carbon (DOC) (mg/L) | -- | -- | -- | -- | -- | -- | -- |
| Total inorganic carbon (mg/L) | -- | -- | -- | -- | -- | -- | -- |
| Total organic carbon (TOC) (mg/L) | -- | -- | -- | -- | -- | -- | -- |
| Carbonate as CaCO ₃ (mg/L) | 2 | 4 | <2 | <2 | <2 | <2 | <2 |
| Cation-Anion Balance % | 0 | 0.9 | -3 | -3.1 | -6.3 | 0 | 0 |
| Chloride (mg/L) | <1 | 2 | 1 | 2 | 1 | <1 | <1 |
| Hardness as CaCO ₃ (mg/L) | 80 | 160 | 47 | 91 | 43 | 40 | 67 |
| Hydroxide as CaCO ₃ (mg/L) | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| pH | -- | -- | -- | -- | -- | -- | -- |
| Total dissolved solids (TDS) (mg/L) | 180 | 340 | 100 | 200 | 100 | 90 | 150 |
| Total suspended solids (TSS) (mg/L) | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Sulfate (mg/L) | 76 | 151 | 48 | 95 | 53 | 39 | 65 |
| Sum of Anions (meq/L) | 2.7 | 5.4 | 1.7 | 3.3 | 1.7 | 1.4 | 2.3 |
| Sum of Cations (meq/L) | 2.7 | 5.5 | 1.6 | 3.1 | 1.5 | 1.4 | 2.3 |
| TDS (calculated) (mg/L) | 163 | 324 | 101 | 197 | 102 | 83 | 137 |
| TDS (ratio - measured/calculated) | 1.1 | 1.05 | 0.99 | 1.02 | 0.98 | 1.08 | 1.09 |
| Total Alkalinity (mg/L) | 57 | 111 | 34 | 66 | 32 | 29 | 47 |

Notes:

Bolded values- analyte concentration detected at a value between MDL and PQL. The associated value is an estimated quantity.

< values - the material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantification limit or the sample detection limit.

mg/L = milligrams per liter.

µg/L = micrograms per liter.

meq/L = milliequivalents per liter.

APPENDIX A: TABLE 7
 WATER-CHEMISTRY PARAMETERS IN STSU WATER USED IN ALL WER TOXICITY TESTS, MEASURED BY GEI LABORATORY UPON SAMPLE COLLECTION AND TOXICITY TEST INITIATION

FREEPORT-MCMORAN CHROMIUM COMPANY
 VADADERO, NEW MEXICO
 SMELTER/TAILINGS SOIL IN-SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Sample ID | Analysis Date | Analysis Temperature (°C) | Total Hardness (mg CaCO ₃ /L) | pH | Alkalinity (mg CaCO ₃ /L) | Conductivity (µmS/cm) | Total Dissolved Solids (mg/L) | Residual Oxygen (mg/L) | Ammonia (mg NH ₃ /L) | Urea Nitrogen (mg N/L) | Total Dissolved Copper (mg/L) | Residual Ammonia (mg/L) |
|------------------------|---------------|---------------------------|--|------|--------------------------------------|-----------------------|-------------------------------|------------------------|---------------------------------|------------------------|-------------------------------|-------------------------|
| Round 1 Samples | | | | | | | | | | | | |
| WER 1-1 | 8/30/2011 | 20 | 90 | 8.03 | 74 | 0.28 | 137 | 8.3 | 0.02 | <0.10 | <0.02 | 0.06 |
| | 9/2/2011 | 20 | 90 | 8 | 74 | 0.274 | 134 | 8.3 | -- | -- | -- | -- |
| WER 1-2 | 8/30/2011 | 20 | 84 | 7.21 | 80 | 0.263 | 129 | 2.7* | 0.02 | <0.10 | <0.02 | 0.06 |
| | 9/2/2011 | 20 | 84 | 7.47 | 80 | 0.265 | 130 | 7.5 | -- | -- | -- | -- |
| WER 1-5 | 9/1/2011 | 20 | 84 | 7.06 | 28 | 0.229 | 114 | 9.1 | 0.03 | <0.10 | <0.02 | 0.14 |
| | 9/4/2011 | 20 | 62 | 7.54 | 28 | 0.222 | 100 | 7.2 | -- | -- | -- | -- |
| WER 1-6 | 9/2/2011 | 20 | 56 | 7 | 44 | 0.157 | 77 | 7.2 | <0.01 | <0.10 | <0.02 | 0.06 |
| | 9/5/2011 | 20 | 54 | 7.57 | 42 | 0.159 | 78 | 7.0 | -- | -- | -- | -- |
| WER 1-7 | 9/1/2011 | 20 | 112 | 7.47 | 86 | 0.294 | 144 | 6.6 | 0.05 | <0.10 | <0.02 | 0.05 |
| | 9/4/2011 | 20 | 106 | 7.93 | 86 | 0.277 | 136 | 7.2 | -- | -- | -- | -- |
| WER 1-9 | 8/31/2011 | 20 | 86 | 7.75 | 94 | 0.227 | 111 | 6.1 | <0.01 | <0.10 | 0.05 | 0.1 |
| | 9/3/2011 | 20 | 88 | 8.04 | 90 | 0.224 | 110 | 7.2 | -- | -- | -- | -- |
| WER 1-10 | 8/31/2011 | 20 | 250 | 7.93 | 244 | 0.601 | 294 | 5.2 | 0.01 | <0.10 | 0.02 | 0.19 |
| | 9/3/2011 | 20 | 262 | 8.31 | 250 | 0.59 | 289 | 7.8 | -- | -- | -- | -- |
| WER 1-11 | 8/31/2011 | 20 | 168 | 7.92 | 160 | 0.371 | 182 | 5.6 | 0.11 | <0.10 | 0.04 | <0.05 |
| | 9/3/2011 | 20 | 154 | 8.22 | 170 | 0.376 | 184 | 7.3 | -- | -- | -- | -- |
| WER 1-12 | 9/3/2011 | 20 | 72 | 8.93 | 30 | 0.216 | 106 | 7.1 | 0.01 | <0.10 | <0.02 | 0.05 |
| | 9/7/2011 | 20 | 76 | 9.35 | 104 | 0.224 | 110 | 7.6 | -- | -- | -- | -- |
| WER 1-RCS | 9/3/2011 | 20 | 44 | 9.14 | 34 | 0.131 | 64 | 7.5 | 0.02 | <0.10 | <0.02 | 0.08 |
| | 9/7/2011 | 20 | 48 | 8.67 | 32 | 0.134 | 66 | 8.5 | -- | -- | -- | -- |
| WER D1-2 | 9/2/2011 | 20 | 52 | 7.66 | 76 | 0.185 | 91 | 9 | 0.2 | <0.10 | <0.02 | <0.05 |
| | 9/5/2011 | 20 | 54 | 8.06 | 76 | 0.190 | 93 | 6.9 | -- | -- | -- | -- |
| WER D2-1 | 9/2/2011 | 20 | 48 | 8.87 | 26 | 0.165 | 81 | 4.7 | 0.04 | <0.10 | <0.02 | 0.07 |
| | 9/5/2011 | 20 | 42 | 8.16 | 28 | 0.166 | 82 | 5.8 | -- | -- | -- | -- |
| Round 2 Samples | | | | | | | | | | | | |
| WER 2-1 | 9/23/2011 | 20 | 102 | 8.09 | 90 | 0.289 | 143 | 7.4 | 0.03 | <0.10 | 0.02 | <0.05 |
| | 9/23/2011 | 20 | 104 | 8.19 | 96 | 0.294 | 144 | 8.1 | -- | -- | -- | -- |
| WER 2-6 | 9/23/2011 | 20 | 50 | 7.09 | 38 | 0.154 | 75 | 5.9 | 0.02 | <0.10 | <0.02 | 0.09 |
| | 9/23/2011 | 20 | 50 | 7.14 | 40 | 0.145 | 71 | 7.4 | -- | -- | -- | -- |
| WER 2-D12 | 9/20/2011 | 20 | 60 | 7.78 | 64 | 0.217 | 106 | 7.5 | 0.03 | <0.10 | <0.02 | 0.11 |
| | 9/23/2011 | 20 | 60 | 7.82 | 64 | 0.210 | 103 | 7.4 | -- | -- | -- | -- |
| WER 2-9 | 9/21/2011 | 20 | 88 | 8.58 | 102 | 0.249 | 122 | 7.5 | 0.02 | <0.10 | 0.1 | <0.05 |
| | 9/24/2011 | 20 | 82 | 8.44 | 102 | 0.242 | 119 | 7.2 | -- | -- | -- | -- |
| WER 2-11 | 9/21/2011 | 20 | 118 | 7.77 | 106 | 0.290 | 142 | 6.7 | 0.07 | <0.10 | <0.02 | 0.07 |
| | 9/24/2011 | 20 | 102 | 7.99 | 106 | 0.287 | 141 | 7.2 | -- | -- | -- | -- |
| WER 2-12 | 9/21/2011 | 20 | 80 | 7.17 | 32 | 0.235 | 116 | 7 | 0.1 | <0.10 | <0.02 | 0.08 |
| | 9/24/2011 | 20 | 80 | 7.4 | 34 | 0.234 | 115 | 7.2 | -- | -- | -- | -- |

Notes:
 < values - the material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantification limit or the sample detection limit.
 * Based on the hardness value measured upon sample collection and test initiation the measured alkalinity value is suspect.
 * aerated 5 minutes to bring D.O. to 6.4 mg/L.
 °C = degrees Celsius.
 mg CaCO₃/L = milligrams calcium carbonate per liter.
 mS/cm = millisiemens per centimeter.
 mg/L = milligrams per liter.
 mg NH₃/L = milligrams ammonia per liter.

APPENDIX A: TABLE 8
 WATER-CHEMISTRY PARAMETERS IN STSIU WATER USED IN THE FIRST ROUND OF WER TOXICITY TESTS, MEASURED BY AN EXTERNAL ANALYTICAL CHEMISTRY LABORATORY (ACZ)

FREEPORT-MCMORAN CHINO MINES COMPANY
 YAMADARI, NEW MEXICO
 SMELTER/TAILINGS SOILS RI SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Parameters | WER-1-1 | WER-1-2 | WER-1-3 | WER-1-4 | WER-1-5 | WER-1-6 | WER-1-7 | WER-1-8 | WER-1-9 | WER-1-10 | WER-1-11 | WER-1-12 | WER-1-RCS | WER-1-D-2 | WER-1-D-3 |
|---------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----------|----------|----------|-----------|-----------|-----------|
| Major Cations (mg/L) | | | | | | | | | | | | | | | |
| Calcium, dissolved | 23.7 | 20 | 17.2 | 12.3 | 26.3 | 19.1 | 56.6 | 34.9 | 17.4 | 9.9 | 13.9 | 11.6 | | | |
| Calcium, total | 24.6 | 20.7 | 17.4 | 12.7 | 27.1 | 19.5 | 57.7 | 35.9 | 18.5 | 10.5 | 14.2 | 11.8 | | | |
| Magnesium, dissolved | 7.7 | 7.5 | 5.2 | 5.7 | 10.3 | 9.3 | 28.2 | 18.8 | 7.4 | 4.8 | 4.2 | 3.7 | | | |
| Magnesium, total | 8.1 | 7.9 | 5.5 | 5.9 | 10.7 | 9.5 | 28.7 | 19.2 | 7.9 | 5.1 | 4.2 | 3.9 | | | |
| Potassium, dissolved | 3 | 2.5 | 3.6 | 3.7 | 5.2 | 3.5 | 4 | 6.9 | 3.1 | 2.3 | 3.0 | 3.3 | | | |
| Sodium, dissolved | 18.7 | 17.6 | 14.5 | 7.2 | 8.8 | 9.4 | 32.2 | 10.5 | 8.3 | 6.2 | 17.8 | 12.1 | | | |
| Metals (µg/L) | | | | | | | | | | | | | | | |
| Aluminum, dissolved | 4 | 6 | 7 | 12 | 7 | 4 | 2 | 21 | 5 | <1 | 42 | 16 | | | |
| Aluminum, total | 32 | 33 | 283 | 87 | 289 | 67 | 32 | 741 | 85 | 14 | 712 | 1600 | | | |
| Cadmium, dissolved | <0.1 | <0.1 | 0.2 | <0.1 | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | | | |
| Cadmium, total | <0.1 | <0.1 | 0.3 | <0.1 | 0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | | | |
| Copper, dissolved | 5.9 | 6.5 | 32.3 | 57.4 | 43 | 7.1 | 5.4 | 4.3 | 2.1 | 5 | 32.3 | 32.8 | | | |
| Copper, total | 7.1 | 8 | 53.1 | 133 | 66.6 | 8.8 | 7.1 | 5.8 | 3 | 6 | 111.3 | 102.2 | | | |
| Iron, dissolved | 90 | <20 | 40 | 80 | <20 | <20 | <20 | <20 | <20 | <20 | 150 | 40 | | | |
| Iron, total | 230 | 80 | 330 | 410 | 300 | 80 | <20 | 460 | 40 | <20 | 590 | 1320 | | | |
| Lead, dissolved | <0.1 | <0.1 | 0.3 | 0.4 | 0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 0.5 | 0.4 | | | |
| Lead, total | 0.1 | 0.1 | 0.3 | 0.3 | 0.2 | <0.1 | <0.1 | 0.3 | <0.1 | <0.1 | 0.7 | 0.9 | | | |
| Manganese, dissolved | 21.6 | 48.8 | 72.7 | 18.2 | 52.1 | 16.3 | 19.4 | 186.6 | 12.2 | 3 | 19.3 | 182.3 | | | |
| Manganese, total | 36.9 | 71.1 | 137.2 | 74.9 | 171.4 | 93 | 28.6 | 258 | 14.7 | 17.7 | 46.7 | 198.6 | | | |
| Zinc, dissolved | 3 | 3 | 8 | 4 | 3 | 3 | 3 | 3 | 3 | <2 | 3 | 8 | | | |
| Zinc, total | 4 | 2 | 10 | 4 | 4 | <2 | 2 | 3 | 4 | 4 | 5 | 7 | | | |
| Water Chemistry | | | | | | | | | | | | | | | |
| Bicarbonate as CaCO3 (mg/L) | 68 | 50 | 24 | 41 | 63 | 87 | 232 | 153 | 27 | 20 | 74 | 24 | | | |
| Dissolved organic carbon (DOC) (mg/L) | 10.7 | 7.8 | 3.5 | 12.5 | 7.8 | 2.5 | 4.7 | 15.7 | 1.2 | 3.2 | 10.0 | 5.8 | | | |
| Total organic carbon (TOC) (mg/L) | 16.2 | 8 | 2.7 | 14.0 | 6.8 | 3.2 | 4.8 | 14.3 | 3 | 4.3 | 9.0 | 6.0 | | | |
| Carbonate as CaCO3 (mg/L) | <2 | <2 | <2 | <2 | <2 | <2 | 6 | 3 | <2 | 3 | <2 | <2 | | | |
| Cation-Anion Balance % | 3.8 | 2.1 | 2.6 | 3.4 | -1.9 | 2.3 | 3.1 | 4 | 2.7 | 0 | 5.8 | 7.1 | | | |
| Chloride (mg/L) | 7 | 7 | 4 | 4 | 4 | 2 | 15 | 8 | 3 | <1 | 3 | 3 | | | |
| Hardness as CaCO3 (mg/L) | 91 | 81 | 64 | 54 | 108 | 86 | 257 | 164 | 74 | 45 | 82 | 44 | | | |
| Hydroxide as CaCO3 (mg/L) | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | | | |
| pH ¹ | 8.2 | 7.8 | 7.5 | 7.5 | 8.0 | 8.2 | 8.3 | 8.3 | 7.2 | 8.6 | 7.9 | 7.0 | | | |
| Total dissolved solids (TDS) (mg/L) | 200 | 200 | 180 | 130 | 210 | 150 | 390 | 240 | 150 | 90 | 150 | 160 | | | |
| Total suspended solids (TSS) (mg/L) | <5 | <5 | 5 | <5 | 9 | <5 | 6 | 10 | <5 | <5 | <5 | 5 | | | |
| Sulfate (mg/L) | 48 | 48 | 65 | 23 | 64 | 17 | 53 | 16 | 58 | 25 | 9 | 37 | | | |
| Sum of Anions (meq/L) | 2.5 | 2.3 | 1.9 | 1.4 | 2.7 | 2.1 | 6.2 | 3.8 | 1.8 | 1.1 | 1.7 | 1.3 | | | |
| Sum of Cations (meq/L) | 2.7 | 2.4 | 2.0 | 1.5 | 2.6 | 2.2 | 6.6 | 3.9 | 1.9 | 1.1 | 1.9 | 1.5 | | | |
| Total Alkalinity (mg/L) | 68 | 50 | 24 | 41 | 63 | 87 | 238 | 156 | 27 | 30 | 74 | 24 | | | |

Notes:
¹ Analysis exceeded method hold time. pH is a field test with no hold time.
 Bolded values - analyte concentration detected at a value between a MDL and PQL. The associated value is an estimated quantity.
 < values - the material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantification limit or the sample detection limit.
 mg/L = milligrams per liter.
 µg/L = micrograms per liter.
 meq/L = milliequivalents per liter.

**APPENDIX A: TABLE 9
WATER-CHEMISTRY PARAMETERS IN STSIU WATER USED IN THE SECOND ROUND OF WER TOXICITY TESTS,
MEASURED BY AN EXTERNAL ANALYTICAL LABORATORY (ACZ)**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Parameters | WER-2-1 | WER-2-6 | WER-2-9 | WER-2-11 | WER-2-12 | WER-2-01-2 |
|---|---------|---------|---------|----------|----------|------------|
| Major Cations (mg/L) | | | | | | |
| Calcium, dissolved | 25.2 | 10.5 | 18.9 | 25.6 | 15.9 | 14.9 |
| Calcium, total | 26.3 | 11 | 19.8 | 26.7 | 19.7 | 15.7 |
| Magnesium, dissolved | 8.2 | 5.1 | 9.3 | 13.3 | 7 | 4.8 |
| Magnesium, total | 8.6 | 5.4 | 10 | 14.1 | 8.6 | 5.1 |
| Potassium, dissolved | 2.6 | 3.1 | 8.4 | 5.2 | 2.8 | 2.6 |
| Sodium, dissolved | 20.2 | 6.4 | 10.5 | 7.8 | 7.4 | 17.1 |
| Metals (µg/L) | | | | | | |
| Aluminum, dissolved | <1 | 5 | 7 | 10 | 8 | <1 |
| Aluminum, total | 29 | 282 | 307 | 1260 | 123 | 1060 |
| Cadmium, dissolved | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Cadmium, total | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Copper, dissolved | 3.4 | 30.2 | 13.7 | 7.9 | 3.6 | 17.9 |
| Copper, total | 4.2 | 48.5 | 20.7 | 10.7 | 4.9 | 43 |
| Iron, dissolved | <20 | 40 | 30 | <20 | <20 | 20 |
| Iron, total | 130 | 400 | 430 | 890 | 70 | 870 |
| Lead, dissolved | <0.1 | <0.1 | 0.2 | 0.2 | 0.2 | <0.1 |
| Lead, total | <0.1 | 0.3 | 0.5 | 0.3 | <0.1 | 0.8 |
| Manganese, dissolved | 3.2 | 17.6 | 33.7 | 30.8 | 18.1 | 11 |
| Manganese, total | 55.4 | 70.9 | 261 | 113.6 | 24.7 | 38.1 |
| Zinc, dissolved | 2 | 3 | 2 | 5 | 4 | 2 |
| Zinc, total | 4 | 3 | 3 | 4 | 3 | 7 |
| Wet Chemistry | | | | | | |
| Bicarbonate as CaCO ₃ (mg/L) | 89 | 36 | 90 | 102 | 31 | 60 |
| Dissolved inorganic carbon (mg/L) | 36.2 | 7.2 | 26.5 | 28.6 | 9.4 | 22.7 |
| Dissolved organic carbon (DOC) (mg/L) | 11 | 11.4 | 12.3 | 12.3 | 3.1 | 10.5 |
| Total inorganic carbon (mg/L) | 23.7 | 11.4 | 24.6 | 27.5 | 8.4 | 17 |
| Total organic carbon (TOC) (mg/L) | 11.2 | 10.2 | 15.1 | 13.5 | 6.5 | 6.4 |
| Carbonate as CaCO ₃ (mg/L) | <2 | <2 | 5 | <2 | <2 | <2 |
| Cation-Anion Balance % | 0 | 4 | 2.2 | 3.7 | -8.1 | 0 |
| Chloride (mg/L) | 8 | 2 | 5 | 6 | 3 | 2 |
| Hardness as CaCO ₃ (mg/L) | 97 | 47 | 86 | 119 | 69 | 57 |
| Hydroxide as CaCO ₃ (mg/L) | <2 | <2 | <2 | <2 | <2 | <2 |
| pH ¹ | 8.2 | 7.5 | 8.5 | 8.1 | 7.7 | 8 |
| Total dissolved solids (TDS) (mg/L) | 210 | 130 | 200 | 190 | 170 | 170 |
| Total suspended solids (TSS) (mg/L) | <5 | <5 | 10 | 6 | 12 | 9 |
| Sulfate (mg/L) | 40.7 | 23.3 | 8.7 | 22.5 | 64.4 | 31.8 |
| Sum of Anions (meq/L) | 2.8 | 1.2 | 2.2 | 2.6 | 2 | 1.9 |
| Sum of Cations (meq/L) | 2.8 | 1.3 | 2.3 | 2.8 | 1.7 | 1.9 |
| Total Alkalinity (mg/L) | 89 | 36 | 95 | 102 | 31 | 60 |

Notes:

¹ Analysis exceeded method hold time. pH is a field test with no hold time.

Bolded values - analyte concentration detected at a value between a MDL and PQL. The associated value is an estimated quantity.

< values - the material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantification limit or the sample detection limit.

mg/L = milligrams per liter.

µg/L = micrograms per liter.

meq/L = milliequivalents per liter.

**APPENDIX A: TABLE 10
WATER-CHEMISTRY PARAMETERS IN STSIU WATERS NOT USED IN WER TOXICITY TESTS, MEASURED BY AN
EXTERNAL ANALYTICAL LABORATORY (ACZ)**

**FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT**

| Parameters | WER-1-D1 | WER-D2-2 | WER-1-BD | WER-MC-1 | WER-1-RCS2 | WER-1-RCS3 |
|---|----------|----------|----------|----------|------------|------------|
| Major Cations (mg/L) | | | | | | |
| Calcium, dissolved | 6.9 | 14.3 | 17.8 | 23.5 | 9 | 15.9 |
| Calcium, total | 7 | 14.3 | 18.3 | 25.4 | 9.5 | 16.8 |
| Magnesium, dissolved | 2.3 | 4.6 | 5.2 | 11.3 | 4.3 | 6.6 |
| Magnesium, total | 2 | 4.6 | 5.4 | 12.1 | 4.5 | 7 |
| Potassium, dissolved | 2.5 | 4.7 | 6.0 | 3.1 | 2.2 | 3 |
| Sodium, dissolved | 6.7 | 12.6 | 7.7 | 12.5 | 4.9 | 7.2 |
| Metals (µg/L) | | | | | | |
| Aluminum, dissolved | 26 | 49 | 13 | 2 | 2 | 2 |
| Aluminum, total | 114 | 582 | 211 | 40 | 21 | 50 |
| Cadmium, dissolved | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Cadmium, total | 0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Copper, dissolved | 21.1 | 18.8 | 94.1 | 8.1 | 5.3 | 2.2 |
| Copper, total | 27.3 | 30.1 | 131.2 | 8.5 | 6.5 | 3.4 |
| Iron, dissolved | 50 | 70 | <20 | <20 | <20 | <20 |
| Iron, total | 290 | 400 | 240 | <20 | <20 | <20 |
| Lead, dissolved | 0.3 | 0.4 | 0.3 | <0.1 | <0.1 | <0.1 |
| Lead, total | 0.6 | 0.3 | 0.2 | <0.1 | <0.1 | <0.1 |
| Manganese, dissolved | 8.6 | 18.1 | 12.5 | 16.6 | 4.4 | 10.4 |
| Manganese, total | 118.7 | 46.1 | 79.4 | 37.6 | 7.3 | 10.8 |
| Zinc, dissolved | 10 | 3 | 2 | <2 | <2 | 2 |
| Zinc, total | 5 | 4 | 3 | 3 | 4 | 9 |
| Wet Chemistry | | | | | | |
| Bicarbonate as CaCO ₃ (mg/L) | 29 | 15 | 42 | 106 | 28 | 28 |
| Dissolved inorganic carbon (mg/L) | -- | -- | -- | -- | -- | -- |
| Dissolved organic carbon (DOC) (mg/L) | 13.1 | 7.5 | 16.9 | 3.9 | 2.5 | 1.7 |
| Total inorganic carbon (mg/L) | -- | -- | -- | -- | -- | -- |
| Total organic carbon (TOC) (mg/L) | 12.4 | 10.2 | 18.5 | 4.8 | 2.4 | 1.2 |
| Carbonate as CaCO ₃ (mg/L) | <2 | <2 | <2 | <2 | <2 | <2 |
| Cation-Anion Balance % | 12.5 | 6.3 | 2.9 | 1.9 | 0 | 3 |
| Chloride (mg/L) | <2 | 4 | 4 | 4 | <1 | 3 |
| Hardness as CaCO ₃ (mg/L) | 27 | 55 | 66 | 105 | 40 | 67 |
| Hydroxide as CaCO ₃ (mg/L) | <2 | <2 | <2 | <2 | <2 | <2 |
| pH ¹ | 7.9 | 7.2 | 7.9 | 8.3 | 7.5 | 7.1 |
| Total dissolved solids (TDS) (mg/L) | 100 | 180 | 160 | 180 | 80 | 130 |
| Total suspended solids (TSS) (mg/L) | <5 | 6 | 6 | 5 | <5 | <5 |
| Sulfate (mg/L) | 10 | 56 | 38 | 20 | 24 | 46 |
| Sum of Anions (meq/L) | 0.7 | 1.5 | 1.7 | 2.6 | 1 | 1.6 |
| Sum of Cations (meq/L) | 0.9 | 1.7 | 1.8 | 2.7 | 1 | 1.7 |
| Total Alkalinity (mg/L) | 29 | 15 | 42 | 108 | 28 | 28 |

Notes:

¹ Analysis exceeded method hold time. pH is a field test with no hold time.

Bolded values- analyte concentration detected at a value between a MDL and PQL. The associated value is an estimated quantity.

< values - the material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantification limit or the sample detection limit.

mg/L = milligrams per liter.

µg/L = micrograms per liter.

meq/L = milliequivalents per liter.

**APPENDIX A: TABLE 11
TOTAL AND DISSOLVED COPPER EXPOSURE CONCENTRATIONS AND DAPHNIA MAGNA SURVIVORSHIP RESULTS MEASURED IN THE FIRST ROUND
OF LABORATORY WATER TOXICITY TESTS**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Sample ID | Nominal Cu (µg/L) | In Water Total Cu (µg/L) | Out Water Total Cu (µg/L) | Total Cu Average (µg/L) | In Water Dissolved Cu (µg/L) | Out Water Dissolved Cu (µg/L) | Dissolved Cu Average (µg/L) | 48-hr Alive / Exposed | 48-Hr Percent Survival | 48-Hr Percent Mortality |
|----------------------|-------------------|--------------------------|---------------------------|-------------------------|------------------------------|-------------------------------|-----------------------------|-----------------------|------------------------|-------------------------|
| <i>Daphnia magna</i> | | | | | | | | | | |
| A-80 | 0 | 2.9 | <0.5 | 1.7 | 3.5 | 1.8 | 2.65 | 19/20 | 95% | 5% |
| A-80 | 4 | 5 | 4 | 4.5 | 8.4 | 3.9 | 6.15 | 19/20 | 95% | 5% |
| A-80 | 6 | 6 | 4.7 | 5.35 | 8.3 | 5.3 | 6.8 | 19/20 | 95% | 5% |
| A-80 | 9 | 8.5 | 6.9 | 7.7 | 9.9 | 7.2 | 8.55 | 18/20 | 90% | 10% |
| A-80 | 13 | 12.2 | 10.4 | 11.3 | 12.6 | 9.2 | 10.9 | 7/20 | 35% | 65% |
| A-80 | 18 | 17.8 | 15.9 | 16.85 | 17.2 | 14.4 | 15.8 | 0/20 | 0% | 100% |
| B-80 | 0 | <0.5 | <0.5 | <0.5 | 3.3 | 0.7 | 2 | 20/20 | 100% | 0% |
| B-80 | 4 | 4.1 | 3.6 | 3.85 | 3.8 | 3.7 | 3.75 | 11/20 | 55% | 45% |
| B-80 | 6 | 5.8 | 5.2 | 5.5 | 5 | 5.1 | 5.05 | 6/20 | 30% | 70% |
| B-80 | 9 | 8.5 | 7.5 | 8 | 7.2 | 7.6 | 7.4 | 7/20 | 35% | 65% |
| B-80 | 13 | 12.1 | 9.8 | 10.95 | <5 | 10.3 | <7.65 | 8/20 | 40% | 60% |
| B-80 | 18 | 19 | 16.9 | 17.95 | 16.6 | 16.9 | 16.75 | 1/20 | 5% | 95% |
| B-150 | 0 | <0.5 | 0.7 | <0.6 | 2.7 | 1.5 | 2.1 | 20/20 | 100% | 0% |
| B-150 | 8 | 8 | 7.3 | 7.65 | 6.6 | 7.1 | 6.85 | 18/20 | 90% | 10% |
| B-150 | 12 | 12.6 | 9.7 | 11.15 | 9.3 | 8.9 | 9.1 | 19/20 | 95% | 5% |
| B-150 | 17 | 16.3 | 14.2 | 15.25 | 13.8 | 13.6 | 13.7 | 16/20 | 80% | 20% |
| B-150 | 24 | 23.4 | 19.8 | 21.6 | 21 | 15 | 18 | 11/20 | 55% | 45% |
| B-150 | 35 | 33.8 | 32.9 | 33.35 | 29.7 | 30.3 | 30 | 6/20 | 30% | 70% |
| C-50 | 0 | <0.5 | 0.6 | <0.55 | 5.6 | 1.7 | 3.65 | 20/20 | 100% | 0% |
| C-50 | 3 | 3.4 | 3.1 | 3.25 | 3.3 | 3.3 | 3.3 | 20/20 | 100% | 0% |
| C-50 | 4 | 4.7 | 4.3 | 4.5 | <5 | 4 | <4.5 | 20/20 | 100% | 0% |
| C-50 | 6 | 6.6 | 5.7 | 6.15 | 6.1 | 5.1 | 5.6 | 18/20 | 90% | 10% |
| C-50 | 9 | 9.2 | 7.4 | 8.3 | 7.6 | 6.8 | 7.2 | 7/20 | 35% | 65% |
| C-50 | 12 | 13.4 | 11.6 | 12.5 | 10.5 | 10.5 | 10.5 | 10/20 | 50% | 50% |
| C-100 | 0 | <0.5 | <0.5 | <0.5 | 6.3 | 2.2 | 4.25 | 20/20 | 100% | 0% |
| C-100 | 6 | 6.5 | 4.7 | 5.6 | 6.1 | 4.5 | 5.3 | 20/20 | 100% | 0% |
| C-100 | 8 | 8.9 | 6.5 | 7.7 | 7.5 | 6.4 | 6.95 | 17/20 | 85% | 15% |
| C-100 | 12 | 12.8 | 10.5 | 11.65 | 10.1 | 9.4 | 9.75 | 18/20 | 90% | 10% |
| C-100 | 17 | 18.4 | 13.3 | 15.85 | 14.1 | 12.3 | 13.2 | 13/20 | 65% | 35% |
| C-100 | 24 | 25.9 | 19.4 | 22.65 | 20.1 | 17.9 | 19 | 2/20 | 10% | 90% |
| D-44 | 0 | <0.5 | <1 | <0.75 | 4.6 | 2.8 | 3.7 | 18/20 | 90% | 10% |
| D-44 | 2 | 2.3 | 2 | 2.15 | 3.9 | 3.7 | 3.8 | 20/20 | 100% | 0% |
| D-44 | 4 | 3.4 | 3 | 3.2 | 3.3 | 4 | 3.65 | 9/20 | 45% | 55% |
| D-44 | 5 | 4.8 | 4.2 | 4.5 | 4.4 | 5 | 4.7 | 13/20 | 65% | 35% |
| D-44 | 7 | 6.9 | 5.9 | 6.4 | 5.6 | 6.1 | 5.85 | 11/20 | 55% | 45% |
| D-44 | 10 | 9.9 | 8.5 | 9.2 | 8 | 8.3 | 8.15 | 5/20 | 25% | 75% |
| E-40 | 0 | <0.5 | 0.6 | <0.55 | <0.5 | <5 | <2.75 | 17/18 | 94% | 6% |
| E-40 | 2 | 2.6 | 2.3 | 2.45 | 3 | 2.5 | 2.75 | 18/19 | 95% | 5% |
| E-40 | 4 | 4 | 4 | 4 | 2.9 | 3 | 2.95 | 11/20 | 55% | 45% |
| E-40 | 5 | 5.4 | 4.8 | 5.1 | 4.3 | 4.1 | 4.2 | 2/20 | 10% | 90% |
| E-40 | 7 | 8.1 | 7.3 | 7.7 | 6 | 5.7 | 5.85 | 2/19 | 11% | 89% |
| E-40 | 10 | 11.5 | 10.7 | 11.1 | 8.8 | 8.3 | 8.55 | 0/20 | 0% | 100% |
| E-70 | 0 | <0.5 | <0.5 | <0.5 | <0.5 | 1.6 | <1.05 | 19/19 | 100% | 0% |
| E-70 | 4 | 4 | 3.4 | 3.7 | 3.3 | 3.5 | 3.4 | 19/20 | 95% | 5% |
| E-70 | 6 | 5.5 | 4.6 | 5.05 | <5 | 4.1 | 4.55 | 17/19 | 89% | 11% |
| E-70 | 8 | 7.7 | 6.1 | 6.9 | 5.9 | 7.2 | 6.55 | 18/20 | 90% | 10% |
| E-70 | 11 | 11.4 | 9 | 10.2 | 9.4 | 9 | 9.2 | 7/20 | 35% | 65% |
| E-70 | 16 | 16.5 | 14.9 | 15.7 | 13.3 | 11.6 | 12.45 | 4/20 | 20% | 80% |

Notes:

In Water = water sampled just before initiation of the toxicity test.

Out Water = water sampled at the completion of the toxicity test.

< values - the material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantification limit or the sample detection limit.

µg/L = micrograms per liter.

**APPENDIX A: TABLE 12
TOTAL AND DISSOLVED COPPER EXPOSURE CONCENTRATIONS AND DAPHNIA MAGNA SURVIVORSHIP RESULTS MEASURED IN THE SECOND
ROUND OF LABORATORY WATER TOXICITY TESTS**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Sample ID | Nominal Cu (µg/L) | In Water Total Cu (µg/L) | Out Water Total Cu (µg/L) | Total Cu Average (µg/L) | In Water Dissolved Cu (µg/L) | Out Water Dissolved Cu (µg/L) | Dissolved Cu Average (µg/L) | 48-hr # Alive/ # Exposed | 48-hr Percent Survival | 48-hr Percent Mortality |
|----------------------|-------------------|--------------------------|---------------------------|-------------------------|------------------------------|-------------------------------|-----------------------------|--------------------------|------------------------|-------------------------|
| Daphnia magna | | | | | | | | | | |
| A2-45 | 0 | <0.5 | <0.5 | <0.5 | 1 | 3.1 | 2.05 | 19/20 | 95% | 5% |
| A2-45 | 4 | 3.2 | 2.8 | 3 | 3.4 | 3.4 | 3.4 | 20/20 | 100% | 0% |
| A2-45 | 5 | 4.8 | 4.4 | 4.6 | 4.3 | 6 | 5.15 | 16/20 | 80% | 20% |
| A2-45 | 7 | 7 | 6.1 | 6.55 | <5 | 6.1 | <5.55 | 10/20 | 50% | 50% |
| A2-45 | 10 | 10 | 8.5 | 9.25 | 8.1 | 7.6 | 7.85 | 2/20 | 10% | 90% |
| A2-100 | 0 | <0.5 | <0.5 | <0.5 | 0.8 | 1.9 | 1.35 | 20/20 | 100% | 0% |
| A2-100 | 12 | 10.6 | 10.3 | 10.45 | 8.1 | 8.6 | 8.35 | 20/20 | 100% | 0% |
| A2-100 | 17 | 15.4 | 15.3 | 15.35 | 11.5 | 12 | 11.75 | 18/20 | 90% | 10% |
| A2-100 | 24 | 22.9 | 21.8 | 22.35 | 17.5 | 17.2 | 17.35 | 6/20 | 30% | 70% |
| B2-75 | 0 | <0.5 | <0.5 | <0.5 | 1 | <0.5 | <0.75 | 20/20 | 100% | 0% |
| B2-75 | 4 | 3.8 | 3 | 3.4 | <5 | 3.3 | 4.15 | 14/20 | 70% | 30% |
| B2-75 | 6 | 5.5 | 4.7 | 5.1 | 4.2 | 4.4 | 4.3 | 15/20 | 75% | 25% |
| B2-75 | 9 | 7.7 | 6.9 | 7.3 | 6 | 6.4 | 6.2 | 11/20 | 55% | 45% |
| B2-75 | 13 | 12.1 | 9.9 | 11 | 8.7 | 8.8 | 8.75 | 7/20 | 35% | 65% |
| B2-75 | 18 | 17.3 | 17.7 | 17.5 | 12.4 | 14.2 | 13.3 | 0/20 | 0% | 100% |
| B2-110 | 0 | 2.2 | <0.5 | <1.35 | <0.5 | <0.5 | <0.5 | 20/20 | 100% | 0% |
| B2-110 | 13 | 11.4 | 11 | 11.2 | 9.8 | 11.1 | 10.45 | 20/20 | 100% | 0% |
| B2-110 | 19 | 16.2 | 14.9 | 15.55 | 13.8 | 7.5 | 10.65 | 18/20 | 90% | 10% |
| B2-110 | 27 | 23.6 | 22.3 | 22.95 | 20.4 | 16.6 | 18.5 | 5/20 | 25% | 75% |

Notes:

In Water = water sampled just before initiation of the toxicity test.

Out Water = water sampled at the completion of the toxicity test.

< values - the material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantification limit or the sample detection limit.

µg/L = micrograms per liter.

**APPENDIX A: TABLE 13
TOTAL AND DISSOLVED COPPER EXPOSURE CONCENTRATIONS AND DAPHNIA MAGNA SURVIVORSHIP RESULTS MEASURED IN THE FIRST ROUND
OF STBIU WATER TOXICITY TESTS**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOLE SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Sample ID | Nominal Cu (µg/L) | In Water Total Cu (µg/L) | Out Water Total Cu (µg/L) | Total Cu Average (µg/L) | In Water Dissolved Cu (µg/L) | Out Water Dissolved Cu (µg/L) | Dissolved Cu Average (µg/L) | 48-hr # Alive # Tested | 48-hr Percent Survival | 48-hr Percent Mortality |
|-----------|-------------------|--------------------------|---------------------------|-------------------------|------------------------------|-------------------------------|-----------------------------|------------------------|------------------------|-------------------------|
| 1-1 | 0 | 7.10 | 7.10 | 7.10 | 5.90 | 5.90 | 5.90 | 20/20 | 100% | 0% |
| 1-1 | 60 | 68.6 | 67 | 67.8 | 76.4 | 55 | 65.7 | 20/20 | 100% | 0% |
| 1-1 | 86 | 92.3 | 92.3 | 92.3 | 82.9 | 77.4 | 80.15 | 18/20 | 90% | 10% |
| 1-1 | 123 | 126 | 131.7 | 128.85 | 111.0 | 115.6 | 113.75 | 12/20 | 60% | 40% |
| 1-1 | 176 | 172.6 | 173.7 | 173.15 | 156.1 | 154.3 | 155.2 | 2/20 | 10% | 90% |
| 1-1 | 251 | 227.1 | 247.6 | 237.35 | 210.1 | 224.4 | 217.25 | 0/20 | 0% | 100% |
| 1-2 | 0 | 8.00 | 7.40 | 7.70 | 6.50 | 6.50 | 6.50 | 20/20 | 100% | 0% |
| 1-2 | 54 | 59.7 | 63.5 | 61.6 | 59 | 56 | 57.5 | 19/20 | 95% | 5% |
| 1-2 | 77 | 80 | 71.4 | 75.7 | 80 | 71.7 | 75.85 | 15/20 | 75% | 25% |
| 1-2 | 110 | 114.8 | 103.2 | 109 | 100.2 | 102.8 | 101.5 | 6/20 | 30% | 70% |
| 1-2 | 156 | 156.9 | 138.6 | 147.75 | 137.6 | 133.7 | 135.65 | 0/20 | 0% | 100% |
| 1-6 | 0 | 133.00 | 127.20 | 130.10 | 57.40 | 57.40 | 57.40 | 19/20 | 95% | 5% |
| 1-6 | 48 | 182.2 | 162.3 | 172.25 | 139 | 147.2 | 143.1 | 16/20 | 80% | 20% |
| 1-6 | 69 | 200.8 | 180.9 | 190.85 | 154.5 | 158.4 | 156.45 | 8/20 | 40% | 60% |
| 1-6 | 98 | 225.3 | 212.3 | 218.8 | 188 | 189.6 | 178.8 | 2/20 | 10% | 90% |
| 1-6 | 140 | 263.9 | 243.2 | 253.55 | 188.5 | 207 | 197.75 | 0/20 | 0% | 100% |
| 1-7 | 0 | 66.60 | 63.60 | 65.10 | 43.00 | 43.00 | 43.00 | 20/20 | 100% | 0% |
| 1-7 | 27 | 96.7 | 88.7 | 92.7 | 76.1 | 80 | 78.05 | 18/20 | 90% | 10% |
| 1-7 | 39 | 110.8 | 93.3 | 102.05 | 85 | 81.3 | 83.15 | 20/20 | 100% | 0% |
| 1-7 | 55 | 123.6 | 113.2 | 118.4 | 96 | 97.3 | 96.65 | 11/20 | 55% | 45% |
| 1-7 | 79 | 147.6 | 125.9 | 136.75 | 112.9 | 108 | 110.45 | 1/20 | 5% | 95% |
| 1-7 | 112 | 177.1 | 161.9 | 169.5 | 137.8 | 139.1 | 138.45 | 0/20 | 0% | 100% |
| 1-9 | 0 | 8.80 | 7.80 | 8.30 | 7.10 | 7.10 | 7.10 | 20/20 | 100% | 0% |
| 1-9 | 34 | 41.1 | 31.9 | 36.5 | 29.9 | 31.2 | 30.55 | 16/20 | 80% | 20% |
| 1-9 | 48 | 54.5 | 47 | 50.75 | 39.50 | 44 | 41.75 | 6/20 | 25% | 75% |
| 1-9 | 69 | 77.2 | 58.6 | 67.9 | 54.6 | 53.4 | 54 | 4/20 | 20% | 80% |
| 1-9 | 99 | 106.7 | 84.9 | 95.8 | 75.4 | 75.9 | 75.65 | 0/20 | 0% | 100% |
| 1-10 | 0 | 5.70 | 5.80 | 5.75 | 5.40 | 5.40 | 5.40 | 20/20 | 100% | 0% |
| 1-10 | 65 | 60.5 | 55.3 | 57.9 | 53.4 | 66 | 59.7 | 20/20 | 100% | 0% |
| 1-10 | 93 | 90.7 | 82 | 86.35 | 79.2 | 79.8 | 79.5 | 18/20 | 90% | 10% |
| 1-10 | 132 | 128.1 | 113.4 | 120.75 | 119 | 118.2 | 118.6 | 15/20 | 75% | 25% |
| 1-10 | 189 | 177.7 | 167 | 172.35 | 157.8 | 168.8 | 163.3 | 6/20 | 30% | 70% |
| 1-10 | 270 | 275 | 229.7 | 252.35 | 221.6 | 224.8 | 223.2 | 0/20 | 0% | 100% |
| 1-11 | 0 | 5.80 | 5.80 | 5.70 | 4.30 | 4.30 | 4.30 | 20/20 | 100% | 0% |
| 1-11 | 94 | 60.4 | 53.6 | 57 | 45.9 | 54.1 | 50 | 20/20 | 100% | 0% |
| 1-11 | 135 | 87.1 | 72.1 | 79.6 | 63.7 | 72.4 | 68.05 | 20/20 | 100% | 0% |
| 1-11 | 193 | 117.6 | 117.2 | 117.4 | 101.5 | 99.4 | 100.45 | 20/20 | 100% | 0% |
| 1-11 | 275 | 188.7 | 160.5 | 164.6 | 134.2 | 142 | 138.1 | 18/20 | 90% | 10% |
| 1-11 | 393 | 230.5 | 232.9 | 231.7 | 188.8 | 187 | 188.9 | 7/20 | 35% | 65% |
| 1-11 | 562 | 339 | 322 | 330.5 | 260.4 | 241.5 | 250.95 | 0/20 | 0% | 100% |
| 1-12 | 0 | 2.50 | 2.40 | 2.45 | 2.10 | 2.10 | 2.10 | 20/20 | 100% | 0% |
| 1-12 | 8 | 9.2 | 8 | 8.6 | 7.6 | 9 | 8.3 | 20/20 | 100% | 0% |
| 1-12 | 11 | 12.3 | 10.1 | 11.2 | 9.9 | 9.7 | 9.8 | 19/20 | 95% | 5% |
| 1-12 | 16 | 16.5 | 14 | 15.25 | 13.1 | 13.5 | 13.3 | 14/20 | 70% | 30% |
| 1-12 | 22 | 25.3 | 19.3 | 22.3 | 17.7 | 16.7 | 17.2 | 6/20 | 25% | 75% |
| 1-12 | 32 | 36.3 | 26.4 | 31.35 | 25.2 | 26 | 25.6 | 0/20 | 0% | 100% |
| 1-RCS | 0 | 6.00 | 6.00 | 6.00 | 5.00 | 5.00 | 5.00 | 19/20 | 95% | 5% |
| 1-RCS | 17 | 22.3 | 22.2 | 22.25 | 18.7 | 18.3 | 18.5 | 19/20 | 95% | 5% |
| 1-RCS | 24 | 26.7 | 25.2 | 25.95 | 21.6 | 22.3 | 21.95 | 17/20 | 85% | 15% |
| 1-RCS | 35 | 37.3 | 36.4 | 36.85 | 31.1 | 30.2 | 30.65 | 6/19 | 32% | 68% |
| 1-RCS | 50 | 50.4 | 54.9 | 52.65 | 45 | 44 | 44.5 | 6/20 | 30% | 70% |
| 1-RCS | 71 | 71.2 | 69.5 | 69.85 | 59.5 | 57.3 | 58.4 | 0/19 | 0% | 100% |
| D1-2 | 0 | 111.30 | 109.20 | 110.25 | 32.30 | 32.30 | 32.30 | 20/20 | 100% | 0% |
| D1-2 | 69 | 178 | 160.4 | 169.2 | 114.6 | 119.2 | 116.9 | 20/20 | 100% | 0% |
| D1-2 | 98 | 205.7 | 184 | 194.85 | 118.2 | 139.2 | 128.7 | 12/20 | 60% | 40% |
| D1-2 | 140 | 241.3 | 273.9 | 257.6 | 114 | 231 | 172.5 | 3/20 | 15% | 85% |
| D1-2 | 200 | 287.8 | 264.3 | 276.05 | 180.1 | 194.2 | 187.15 | 0/20 | 0% | 100% |
| D2-1 | 0 | 102.20 | 102.20 | 102.20 | 32.80 | 32.80 | 32.80 | 20/20 | 100% | 0% |
| D2-1 | 57 | 163.8 | 144.5 | 154.15 | 51.6 | 98 | 74.8 | 7/20 | 35% | 65% |
| D2-1 | 82 | 180.4 | 161.1 | 170.75 | 107 | 110.8 | 108.9 | 4/20 | 20% | 80% |
| D2-1 | 117 | 215.1 | 207 | 211.05 | 74.4 | 130.5 | 102.45 | 0/20 | 0% | 100% |

Notes:

¹ Number was reported as 20.8 µg/L in the GEI Whole Effluent Toxicity Testing Report but is reported correctly as 50.75 in the above table.

In Water = water sampled just before initiation of the toxicity test.

Out Water = water sampled at the completion of the toxicity test.

µg/L = micrograms per liter.

**APPENDIX A: TABLE 14
TOTAL AND DISSOLVED COPPER EXPOSURE CONCENTRATIONS AND *DAPHNIA MAGNA* SURVIVORSHIP RESULTS MEASURED IN THE SECOND
ROUND OF STSIU WATER TOXICITY TESTS**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS U SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Sample ID | Nominal Cu (µg/L) | In Water Total Cu (µg/L) | Out Water Total Cu (µg/L) | Total Cu Average (µg/L) | In Water Dissolved Cu (µg/L) | Out Water Dissolved Cu (µg/L) | Dissolved Cu Average (µg/L) | 48-hr # Alive / # Exposed | 48-hr Percent Survival | 48-hr Percent Mortality |
|-----------|-------------------|--------------------------|---------------------------|-------------------------|------------------------------|-------------------------------|-----------------------------|---------------------------|------------------------|-------------------------|
| 2-1 | 0 | 4.20 | 4.20 | 4.20 | 3.40 | 3.40 | 3.40 | 19/20 | 95% | 5% |
| 2-1 | 48 | 46.50 | 42.00 | 44.25 | 42 | 36.6 | 39.3 | 19/20 | 95% | 5% |
| 2-1 | 69 | 65.70 | 60.30 | 63.00 | 53.5 | 48.4 | 50.95 | 19/20 | 95% | 5% |
| 2-1 | 98 | 90.70 | 68.70 | 79.70 | 75.5 | 53.1 | 64.3 | 17/20 | 85% | 15% |
| 2-1 | 140 | 135.8 | 126.9 | 131.4 | 102.1 | 99.5 | 100.8 | 1/20 | 5% | 95% |
| 2-1 | 200 | 189.2 | 181.6 | 185.4 | 153 | 140 | 146.5 | 1/20 | 5% | 95% |
| 2-1 | 286 | 265.7 | 262.3 | 264.0 | 211 | 218.7 | 214.85 | 0/20 | 0% | 100% |
| 2-6 | 0 | 48.50 | 46.90 | 47.70 | 30.20 | 30.20 | 30.20 | 20/20 | 100% | 0% |
| 2-6 | 51 | 95.3 | 94.5 | 94.9 | 78.2 | 74.2 | 76.2 | 3/20 | 15% | 85% |
| 2-6 | 73 | 116 | 116.8 | 116.4 | 89.5 | 92 | 90.75 | 3/20 | 15% | 85% |
| 2-6 | 104 | 147.4 | 145 | 146.2 | 114.8 | 107 | 110.9 | 0/20 | 0% | 100% |
| 2-9 | 0 | 18.60 | 20.70 | 19.65 | 13.70 | 13.70 | 13.70 | 20/20 | 100% | 0% |
| 2-9 | 42 | 55.9 | 55.4 | 55.7 | 50.3 | 43.6 | 46.95 | 19/20 | 95% | 5% |
| 2-9 | 122 | 128.7 | 138.8 | 133.8 | 97.5 | 104.9 | 101.2 | 20/20 | 100% | 0% |
| 2-9 | 174 | 177 | 188.8 | 182.9 | 148 | 137.8 | 142.9 | 14/20 | 70% | 30% |
| 2-9 | 249 | 241 | 265.8 | 253.4 | 187.6 | 181.8 | 184.7 | 12/20 | 60% | 40% |
| 2-11 | 0 | 9.80 | 9.80 | 9.80 | 7.90 | 7.90 | 7.90 | 20/20 | 100% | 0% |
| 2-11 | 87 | 84.5 | 78.3 | 81.4 | 69.5 | 50.8 | 60.15 | 19/20 | 95% | 5% |
| 2-11 | 124 | 119.5 | 115.2 | 117.4 | 91.7 | 74.2 | 82.95 | 19/20 | 95% | 5% |
| 2-11 | 178 | 167.1 | 155 | 161.1 | 128.5 | 101.9 | 115.2 | 15/20 | 75% | 25% |
| 2-11 | 254 | 234.4 | 228.7 | 231.6 | 171.7 | 145.2 | 158.45 | 8/20 | 40% | 60% |
| 2-11 | 363 | 325.3 | 306.2 | 315.8 | 241.6 | 192 | 216.8 | 0/20 | 0% | 100% |
| 2-12 | 0 | 4.70 | 4.00 | 4.35 | 3.60 | 3.60 | 3.60 | 19/20 | 95% | 5% |
| 2-12 | 29 | 30.1 | 27.7 | 28.9 | 29.2 | 23.1 | 26.15 | 18/20 | 90% | 10% |
| 2-12 | 41 | 40.9 | 36.8 | 38.9 | 40 | 29.4 | 34.7 | 9/20 | 45% | 55% |
| 2-12 | 58 | 55.7 | 52 | 53.9 | 50.1 | 40 | 45.05 | 3/20 | 15% | 85% |
| 2-12 | 83 | 77.8 | 71.6 | 74.7 | 68 | 59 | 63.5 | 0/20 | 0% | 100% |
| D1-2 | 0 | 41.10 | 27.00 | 34.05 | 17.90 | 17.90 | 17.90 | 18/20 | 90% | 10% |
| D1-2 | 57 | 89.7 | 78.2 | 84.0 | 60 | 56.7 | 58.35 | 17/20 | 85% | 15% |
| D1-2 | 82 | 112.5 | 95.5 | 104.0 | 78.2 | 66.3 | 72.25 | 5/20 | 25% | 75% |
| D1-2 | 117 | 142.1 | 127.5 | 134.8 | 95.2 | 82.2 | 88.7 | 0/20 | 0% | 100% |

Notes:

In Water = water sampled just before initiation of the toxicity test.

Out Water = water sampled at the completion of the toxicity test.

µg/L = micrograms per liter.

**APPENDIX A: TABLE 15
TOTAL AND DISSOLVED COPPER MEDIAN EFFECT CONCENTRATIONS (EC50s) CALCULATED FOR
ALL DAPHNIA MAGNA LABORATORY WATER TOXICITY TESTS**

**FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT**

| Sample ID | Sample Hardness (mg CaCO ₃ /L) | Total Copper EC50 (µg/L) | Normalized Total Copper EC50 (µg/L) | Dissolved Copper EC50 (µg/L) | Normalized Dissolved Copper EC50 (µg/L) | Statistical Method for EC50 Calculation |
|---|---|--------------------------|-------------------------------------|------------------------------|---|---|
| Round 1 Laboratory Water Samples | | | | | | |
| A-80 | 80 | 10.57 | 13.04 | 10.14 | 12.52 | Probit |
| B-80* | 78 | 4.552 | 5.753 | 4.370 | 5.522 | Probit |
| B-150 | 168 | 25.45 | 15.61 | 24.43 | 14.98 | Probit |
| C-50 | 50 | 10.10 | 19.40 | 9.6939 | 18.63 | Probit |
| C-100 | 98 | 16.23 | 16.54 | 15.576 | 15.88 | Probit |
| D-44 | 46 | 6.284 | 13.06 | 6.033 | 12.54 | Probit |
| E-40 | 42 | 4.142 | 9.379 | 3.976 | 9.004 | Probit |
| E-70 | 72 | 9.854 | 13.43 | 9.4598 | 12.89 | Probit |
| Round 2 Laboratory Water Samples | | | | | | |
| A2-45 | 42 | 6.440 | 14.58 | 6.183 | 14.00 | Probit |
| A2-100 | 96 | 20.05 | 20.83 | 19.24 | 20.00 | Probit |
| B2-75 | 72 | 6.871 | 9.363 | 6.596 | 8.989 | Probit |
| B2-110 | 100 | 20.08 | 20.08 | 19.28 | 19.28 | Probit |
| Geometric Mean | | | 14.53 | | 13.95 | |

Notes:

µg/L = micrograms per liter.

Normalized EC50 = Normalized to a hardness of 100 mg CaCO₃/L using hardness slope of 0.9422.

* = unacceptable for use in interpreting WER results because alkalinity was less than the appropriate range for the sample hardness.

**APPENDIX A: TABLE 16
TOTAL AND DISSOLVED COPPER MEDIAN EFFECT CONCENTRATIONS (EC50s) CALCULATED FOR ALL DAPHNIA MAGNA STSIU
WATER TOXICITY TESTS**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Site Water ID | Matched Laboratory Water ID | Site Water Hardness (mg CaCO ₃ /L) | Site Water EC50 (µg Total Cu/L) | Normalized Site Water EC50 (µg Total Cu/L) | Site Water EC50 (µg Dissolved Cu/L) | Normalized Site Water EC50 (µg Dissolved Cu/L) | EC50 Statistical Method |
|------------------------|-----------------------------|---|---------------------------------|--|-------------------------------------|--|-------------------------|
| Round 1 Samples | | | | | | | |
| WER 1-1 | A-80 | 90 | 131.2 | 144.8 | 116.3 | 128.4 | Probit |
| WER 1-2 | A-80 | 84 | 91.49 | 107.8 | 87.4 | 103.0 | Probit |
| WER 1-5 ^a | C-50 | 62 | <53.1 | -- | <32.3 | -- | -- |
| WER 1-6 | D-44 | 54 | 189.3 | 338.2 | 155.7 | 278.2 | Probit |
| WER 1-7 | C-100 | 106 | 118.0 | 111.7 | 96.2 | 91.09 | Probit |
| WER 1-9 | A-80 ¹ | 88 | 45.78 | 51.64 | 37.8 | 42.61 | Probit |
| WER 1-10 | B-150 | 262 | 141.3 | 57.01 | 134.2 | 54.15 | Probit |
| WER 1-11 | C-100 ¹ | 154 | 212.3 | 141.4 | 172.8 | 115.0 | Probit |
| WER 1-12 | E-70 | 76 | 17.8 | 23.08 | 14.7 | 19.09 | Probit |
| WER 1-RCS | E-40 | 48 | 37.8 | 75.39 | 31.7 | 63.21 | Probit |
| WER D1-2 | D-44 | 54 | 211.3 | 377.6 | 141.6 | 253.0 | Probit |
| WER D2-1 | E-40 ¹ | 42 | 148.8 | 336.9 | 68.4 | 155.0 | Probit |
| Round 2 Samples | | | | | | | |
| WER 2-1 | A2-100 | 104 | 102.81 | 99.08 | 81.06 | 78.12 | Probit |
| WER 2-6 | A2-45 | 50 | 81.14 | 155.9 | 61.82 | 118.8 | Probit |
| WER 2-9 ^b | B2-75 | 82 | >253.4 | >305.4 | >184.7 | >222.7 | -- |
| WER 2-11 | B2-110 | 102 | 194.1 | 190.5 | 135.5 | 133.0 | Probit |
| WER 2-12 | B2-75 | 80 | 40.02 | 49.39 | 35.23 | 43.48 | Probit |
| WER 2-D1-2 | A2-45 | 60 | 98.19 | 158.9 | 68.31 | 110.5 | Probit |

Notes:

STSIU = Smelter/Tailing Soil Investigation Unit.

- a. No exposure treatment adversely affected less than 50% of test organisms; therefore the EC50 concentration is less than the lowest Cu concentration.
 - b. No exposure treatment adversely affected more than 50% of test organisms therefore the EC50 concentration is greater than the highest Cu concentration.
 - 1. To satisfy testing requirements, the matched laboratory control was switched.
- mg CaCO₃/L = milligrams calcium carbonate per liter.
µg Cu/L = micrograms copper per liter.
Normalized EC50 = Normalized to a hardness of 100 mg CaCO₃/L using hardness slope of 0.9422.

APPENDIX A: TABLE 17
 TOTAL COPPER WERs FOR DAPHNIA MAGNA, CALCULATED USING FOUR DIFFERENT DENOMINATORS IN THE WER CALCULATION

FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADURUM, NEW MEXICO
 SMELTER/TAILINGS SOILS KU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Site Water | Match Laboratory Control ID | STSIU Site Water | | | Laboratory Dilution Water | | | Water Effect Values (WERs) | | | |
|-------------------------|-----------------------------|------------------------------------|----------------|---------------------------|------------------------------------|----------------|---------------------------|---|--|---|---|
| | | Hardness (mg CaCO ₃ /L) | EC50 (µg Cu/L) | Normalized EC50 (µg Cu/L) | Hardness (mg CaCO ₃ /L) | EC50 (µg Cu/L) | Normalized EC50 (µg Cu/L) | Matched Lab Water Normalized EC50 used in WER Denominator | SMAV from USEPA (2001) used in WER Denominator | Matched EC50 from USEPA (2001) SMAV used in WER Denominator | Geometric Mean of Lab Water EC50s used in WER Denominator |
| <i>Normal 1 Samples</i> | | | | | | | | | | | |
| WER 1-1 | A-80 | 90 | 131.2 | 144.8 | 80 | 10.57 | 13.04 | 11.11 | 7.199 | 8.428 | 9.992 |
| WER 1-2 | A-80 | 84 | 91.49 | 107.8 | 80 | 10.57 | 13.04 | 8.270 | 5.359 | 6.272 | 7.416 |
| WER 1-5 ^a | C-50 | 62 | <53.1 | — | 50 | 10.10 | 19.40 | — | — | — | — |
| WER 1-6 | D-44 | 54 | 189.3 | 338.2 | 46 | 6.284 | 13.06 | 25.89 | 16.81 | 19.68 | 23.26 |
| WER 1-7 | C-100 | 106 | 118.0 | 111.7 | 98 | 16.23 | 16.54 | 6.755 | 5.552 | 6.498 | 7.682 |
| WER 1-9 | A-80 | 88 | 45.78 | 51.84 | 80 | 10.57 | 13.04 | 3.900 | 2.566 | 3.004 | 3.551 |
| WER 1-10 | B-150 | 262 | 141.3 | 57.01 | 168 | 25.45 | 15.81 | 3.853 | 2.833 | 3.316 | 3.921 |
| WER 1-11 | C-100 | 154 | 212.3 | 141.4 | 98 | 16.23 | 16.54 | 8.548 | 7.026 | 8.223 | 9.722 |
| WER 1-12 | E-70 | 76 | 17.82 | 23.08 | 72 | 9.854 | 13.43 | 1.719 | 1.147 | 1.343 | 1.587 |
| WER 1-RCS | E-40 | 48 | 37.75 | 75.39 | 42 | 4.142 | 9.379 | 8.038 | 3.747 | 4.385 | 5.185 |
| WER D1-2 | D-44 | 54 | 211.3 | 377.8 | 46 | 6.284 | 13.06 | 28.91 | 18.77 | 21.97 | 25.97 |
| WER D2-1 ^b | D-44 | 42 | 148.8 | 336.9 | 46 | 6.284 | 13.06 | 25.79 | 16.74 | 19.60 | 23.17 |
| <i>Normal 2 Samples</i> | | | | | | | | | | | |
| WER 2-1 | A2-100 | 104 | 102.8 | 99.08 | 98 | 20.05 | 20.83 | 4.758 | 4.924 | 5.784 | 6.614 |
| WER 2-6 ^c | A2-45 | 50 | 81.14 | 155.9 | 42 | 6.440 | 14.58 | 10.69 | 7.749 | 9.070 | 10.72 |
| WER 2-6 ^c | B2-75 | 82 | >253.4 | >305.4 | 72 | 6.871 | 9.383 | >32.62 | >15.18 | >17.77 | >21.011 |
| WER 2-11 | B2-110 | 102 | 194.1 | 190.5 | 100 | 20.08 | 20.08 | 9.485 | 9.468 | 11.08 | 13.10 |
| WER 2-12 | B2-75 | 80 | 40.02 | 49.39 | 72 | 6.871 | 9.383 | 5.275 | 2.455 | 2.873 | 3.397 |
| WER 2-D12 | A2-45 | 60 | 98.19 | 158.9 | 42 | 6.440 | 14.58 | 10.90 | 7.897 | 9.244 | 10.93 |

- Notes:
- STSIU = Smelter/Tailing Soil Investigation Unit.
 - a. No exposure treatment adversely affected less than 50% of test organisms; therefore the EC50 concentration is less than the lowest Cu concentration.
 - b. Other than the control, no exposure treatment adversely affected less than 50% of test organisms; estimated EC50s are based on Probit Analysis.
 - c. No exposure treatment adversely affected more than 50% of test organisms; therefore the EC50 concentration is greater than the highest Cu concentration and the WER is calculated using the > EC50 value.
- Normalized EC50 = Normalized to a hardness of 100 mg CaCO₃/L using hardness slope of 0.9422.
- WER Calculations: Normalized Site Water EC50 / each of the following four denominators.
- I. Matched laboratory water EC50 normalized to 100 mg/L hardness.
 - II. 20.12 = SMAV reported by USEPA (2001) for total copper at 100 hardness, including nominal and measured values.
 - III. 17.19 = SMAV calculated using only the measured EC50 values at 100 mg/L hardness reported by USEPA (2001).
 - IV. 14.54 = Geometric mean of the 11 normalized laboratory water copper EC50 values conducted side-by-side with site water toxicity tests.

**APPENDIX A: TABLE 18
DISSOLVED COPPER WERs FOR DAPHNIA MAGNA, CALCULATED USING FOUR DIFFERENT DENOMINATORS IN THE WER CALCULATION**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Site Water | Match Laboratory Control ID | STSIU Site Water | | | Laboratory Dilution Water | | | Water Effect Ratios (WER) | | | |
|------------------------|-----------------------------|------------------------------------|----------------|---------------------------|------------------------------------|----------------|---------------------------|--|--|--|--|
| | | Hardness (mg CaCO ₃ /L) | EC50 (µg Cu/L) | Normalized EC50 (µg Cu/L) | Hardness (mg CaCO ₃ /L) | EC50 (µg Cu/L) | Normalized EC50 (µg Cu/L) | I. Matched Lab Water Normalized EC50 used in WER Denominator | II. SMAV from USEPA (2001) used in WER Denominator | III. Measured EC50s from USEPA (2001) SMAV used in WER Denominator | IV. Geometric Mean of Lab Water Normalized EC50s used in WER Denominator |
| Room 12 Samples | | | | | | | | | | | |
| WER 1-1 | A-80 | 90 | 116.3 | 128.4 | 80 | 10.14 | 12.52 | 10.26 | 6.651 | 7.783 | 9.200 |
| WER 1-2 | A-80 | 84 | 87.39 | 103.0 | 80 | 10.14 | 12.52 | 8.23 | 5.334 | 6.242 | 7.378 |
| WER 1-5 ^a | C-60 | 82 | <32.3 | — | 50 | 9.894 | 18.63 | — | — | — | — |
| WER 1-6 | D-44 | 54 | 155.7 | 278.2 | 46 | 6.033 | 12.54 | 22.19 | 14.41 | 16.86 | 19.93 |
| WER 1-7 | C-100 | 106 | 96.23 | 91.09 | 98 | 15.58 | 15.88 | 5.738 | 4.717 | 5.521 | 6.525 |
| WER 1-9 | A-80 | 88 | 37.78 | 42.61 | 80 | 10.14 | 12.52 | 3.404 | 2.207 | 2.582 | 3.052 |
| WER 1-10 | B-150 | 282 | 134.2 | 54.15 | 168 | 24.43 | 14.98 | 3.614 | 2.804 | 3.282 | 3.879 |
| WER 1-11 | C-100 | 154 | 172.8 | 115.0 | 98 | 15.58 | 15.88 | 7.245 | 5.956 | 6.971 | 8.239 |
| WER 1-12 | E-70 | 76 | 14.74 | 19.09 | 72 | 9.460 | 12.89 | 1.481 | 0.969 | 1.157 | 1.368 |
| WER 1-RCS | E-40 | 48 | 31.65 | 63.21 | 42 | 3.976 | 9.004 | 7.020 | 3.273 | 3.831 | 4.528 |
| WER D1-2 | D-44 | 54 | 141.6 | 253.0 | 46 | 6.033 | 12.54 | 20.18 | 13.10 | 15.34 | 18.13 |
| WER D2-1 ^b | D-44 | 42 | 68.45 | 155.0 | 46 | 6.033 | 12.54 | 12.36 | 8.027 | 9.394 | 11.10 |
| Room 12 Samples | | | | | | | | | | | |
| WER 2-1 | A2-100 | 104 | 81.06 | 78.12 | 96 | 19.24 | 20.00 | 3.907 | 4.046 | 4.735 | 5.596 |
| WER 2-6 ^c | A2-45 | 50 | 61.82 | 118.8 | 42 | 6.183 | 14.00 | 8.484 | 6.151 | 7.199 | 8.508 |
| WER 2-9 ^d | B2-75 | 82 | >184.7 | >222.7 | 72 | 6.596 | 8.989 | >24.77 | >11.53 | >13.49 | >15.95 |
| WER 2-11 | B2-110 | 102 | 135.5 | 133.0 | 100 | 19.28 | 19.28 | 6.900 | 6.889 | 8.063 | 9.530 |
| WER 2-12 | B2-75 | 80 | 35.23 | 43.48 | 72 | 6.596 | 8.989 | 4.837 | 2.251 | 2.635 | 3.114 |
| WER 2-D12 | A2-45 | 60 | 68.31 | 110.5 | 42 | 6.183 | 14.00 | 7.895 | 5.724 | 6.699 | 7.918 |

Notes:

STSIU = Smelter/Tailing Soil Investigation Unit

- a. No exposure treatment adversely affected less than 50% of test organisms; therefore the EC50 concentration is less than the lowest Cu concentration.
- b. Other than the control, no exposure treatment adversely affected less than 50% of test organisms; estimated EC50s are based on Probit Analysis.
- c. No exposure treatment adversely affected more than 50% of test organisms; therefore the EC50 concentration is greater than the highest Cu concentration and the WER is calculated using the > EC50 value.

Normalized EC50 = Normalized to a hardness of 100 mg CaCO₃/L using hardness slope of 0.9422.

WER Calculations: Normalized Site Water EC50 / each of the following four denominators.

- I. Matched laboratory water EC50 normalized to 100 mg/L hardness.
- II. 19.31 = SMAV reported by USEPA (2001) for dissolved copper at 100 hardness, including nominal and measured values.
- III. 16.50 = SMAV calculated using only the measured EC50 values at 100 mg/L hardness reported by USEPA (2001).
- IV. 13.96 = Geometric mean of the 11 normalized laboratory water copper EC50 values conducted side-by-side with site water toxicity tests.

APPENDIX A: TABLE 19
VERIFICATION CALCULATIONS OF DISSOLVED COPPER WERs THAT WERE CALCULATED FOR DAPHNIA MAGNA USING THE MATCHED LABORATORY WATER EC50 IN THE WER DENOMINATOR

FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SMELTER/TAILINGS SOILS RIJ SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Site Water ID | SPBU Site Water Cu EC50s | | | Match Laboratory Water Cu EC50s | | | Water Effect Ratios (WER) listed in Tables 17 and 18 | | Verification of Dissolved Cu WERs based on Total Cu | |
|---------------------------|--------------------------|--------------------|----------------|---------------------------------|--------------------|----------------|--|---|---|-----------|
| | Total Cu (ppb) | Dissolved Cu (ppb) | % Dissolved Cu | Total Cu (ppb) | Dissolved Cu (ppb) | % Dissolved Cu | WER _{EC50} | Site Water EC50 (ppb) Lab Water EC50 (ppb) | Dissolved WER | Total WER |
| | | | | | | | | | | |
| Downstream Samples | | | | | | | | | | |
| WER 1-1 | 144.8 | 128.4 | 88.67% | 13.04 | 12.51 | 95.97% | 11.11 | 10.26 | | 10.26 |
| WER 1-2 | 107.8 | 103.0 | 95.52% | 13.04 | 12.51 | 95.97% | 8.270 | 8.229 | | 8.231 |
| WER 1-5 ^a | - | - | - | 19.40 | 18.82 | 95.97% | - | - | | - |
| WER 1-6 | 338.2 | 278.2 | 82.25% | 13.06 | 12.53 | 95.97% | 25.89 | 22.19 | | 22.19 |
| WER 1-7 | 111.7 | 91.09 | 81.55% | 16.54 | 15.87 | 95.97% | 6.755 | 5.738 | | 5.740 |
| WER 1-9 | 51.64 | 42.81 | 82.52% | 13.04 | 12.51 | 95.97% | 3.960 | 3.404 | | 3.405 |
| WER 1-10 | 57.01 | 54.15 | 94.99% | 15.61 | 14.98 | 95.97% | 3.653 | 3.614 | | 3.615 |
| WER 1-11 | 141.4 | 115.0 | 81.36% | 16.54 | 15.87 | 95.97% | 6.548 | 7.245 | | 7.247 |
| WER 1-12 | 23.08 | 19.09 | 82.73% | 13.43 | 12.89 | 95.97% | 1.719 | 1.481 | | 1.481 |
| WER 1-RCS | 75.39 | 63.21 | 83.85% | 9.379 | 9.00 | 95.97% | 8.038 | 7.020 | | 7.022 |
| WER D1-2 | 377.6 | 253.0 | 67.01% | 13.06 | 12.53 | 95.97% | 28.91 | 20.18 | | 20.19 |
| WER D2-1 ^b | 336.9 | 155.0 | 46.01% | 13.06 | 12.53 | 95.97% | 25.79 | 12.36 | | 12.37 |
| Upstream Samples | | | | | | | | | | |
| WER 2-1 | 99.08 | 78.12 | 78.85% | 120.83 | 19.89 | 95.97% | 4.756 | 3.907 | | 3.908 |
| WER 2-6 ^b | 155.9 | 118.8 | 76.18% | 14.584 | 14.00 | 95.97% | 10.89 | 8.484 | | 8.487 |
| WER 2-9 ^c | >305.4 | >222.7 | 72.92% | 9.363 | 8.99 | 95.97% | >32.62 | >24.77 | | >24.79 |
| WER 2-11 | 190.5 | 133.0 | 69.84% | 20.08 | 19.27 | 95.97% | 9.485 | 6.900 | | 6.902 |
| WER 2-12 | 49.39 | 43.48 | 88.03% | 9.363 | 8.99 | 95.97% | 5.275 | 4.837 | | 4.838 |
| WER 2-D12 | 158.9 | 110.5 | 69.56% | 14.584 | 14.00 | 95.97% | 10.90 | 7.895 | | 7.898 |

Notes:
 a. No exposure treatment adversely affected less than 50% of test organisms; therefore the EC50 concentration is less than the lowest Cu concentration.
 b. Other than the control no exposure treatment adversely affected less than 50% of test organisms; estimated EC50s are based on Probit Analysis.
 c. No exposure treatment adversely affected more than 50% of test organisms; therefore the EC50 concentration is greater than the highest Cu concentration and the WER is calculated using the > EC50 value.
 d. Dissolved EC50 values were calculated using the 0.06 dissolved to total conversion factor at 0.06 from USEPA 2001 and 2007
 Normalized EC50 = Normalized to a hardness of 100 mg CaCO3/L using hardness slope of 0.0422.
 µg/L = micrograms per liter.

**APPENDIX A: TABLE 20
VERIFICATION CALCULATIONS OF DISSOLVED COPPER WERs THAT WERE CALCULATED USING THE DAPHNIA MAGNA SPECIES MEAN ACUTE VALUE IN THE WER DENOMINATOR**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADRIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IN-SITE SPECIFIC COPPER TOXICITY MODEL REPORT

| Site Water ID | STSUI Site Water Cu EC50s | | | SMAV From USEPA 2001 | | | Water Effect Ratios (WER) listed in Tables 17 and 18 | | Verification of Dissolved Cu WERs based on Total Cu | |
|------------------------|---------------------------|---------------------|----------------|----------------------|----------------------------------|----------------|---|--|---|--------------|
| | Total Cu (µg/L) | Dissolved Cu (µg/L) | % Dissolved Cu | Total Cu (µg/L) | Dissolved Cu ^a (µg/L) | % Dissolved Cu | WER = Site Water EC50 (µg/L) ^a SMAV (µg/L) | Dissolved WER = % Dissolved Cu (µg/L) / % Total WER | % Dissolved Cu (µg/L) / % Total WER | |
| | | | | | | | | | | Total Cu WER |
| Round 1 Samples | | | | | | | | | | |
| WER 1-1 | 144.8 | 128.4 | 88.67% | 20.12 | 19.31 | 95.97% | 7.199 | 6.651 | 6.651 | |
| WER 1-2 | 107.8 | 103.0 | 95.52% | 20.12 | 19.31 | 95.97% | 5.359 | 5.334 | 5.334 | |
| WER 1-5 ^a | — | — | — | 20.12 | 19.31 | 95.97% | — | — | — | |
| WER 1-6 | 338.2 | 278.2 | 82.25% | 20.12 | 19.31 | 95.97% | 16.81 | 14.41 | 14.41 | |
| WER 1-7 | 111.7 | 91.09 | 81.55% | 20.12 | 19.31 | 95.97% | 5.552 | 4.717 | 4.717 | |
| WER 1-9 | 51.64 | 42.61 | 82.52% | 20.12 | 19.31 | 95.97% | 2.566 | 2.207 | 2.207 | |
| WER 1-10 | 57.01 | 54.15 | 94.99% | 20.12 | 19.31 | 95.97% | 2.833 | 2.804 | 2.804 | |
| WER 1-11 | 141.4 | 115.0 | 81.36% | 20.12 | 19.31 | 95.97% | 7.026 | 5.956 | 5.956 | |
| WER 1-12 | 23.06 | 19.09 | 82.73% | 20.12 | 19.31 | 95.97% | 1.147 | 0.9887 | 0.989 | |
| WER 1-RCS | 75.39 | 63.21 | 83.85% | 20.12 | 19.31 | 95.97% | 3.747 | 3.273 | 3.273 | |
| WER D1-2 | 377.6 | 253.0 | 67.01% | 20.12 | 19.31 | 95.97% | 18.77 | 13.10 | 13.10 | |
| WER D2-1 ^b | 338.9 | 155.0 | 46.01% | 20.12 | 19.31 | 95.97% | 16.74 | 8.027 | 8.027 | |
| Round 2 Samples | | | | | | | | | | |
| WER 2-1 | 99.06 | 78.12 | 78.85% | 20.12 | 19.31 | 95.97% | 4.924 | 4.046 | 4.046 | |
| WER 2-6 ^c | 155.9 | 118.8 | 76.18% | 20.12 | 19.31 | 95.97% | 7.749 | 6.151 | 6.151 | |
| WER 2-9 ^d | >305.4 | >222.7 | 72.92% | 20.12 | 19.31 | 95.97% | >15.18 | >11.53 | >11.54 | |
| WER 2-11 | 190.5 | 133.0 | 69.84% | 20.12 | 19.31 | 95.97% | 9.468 | 6.889 | 6.889 | |
| WER 2-12 | 49.39 | 43.48 | 88.03% | 20.12 | 19.31 | 95.97% | 2.455 | 2.251 | 2.251 | |
| WER 2-D12 | 158.9 | 110.5 | 69.56% | 20.12 | 19.31 | 95.97% | 7.897 | 5.724 | 5.724 | |

Notes:

- a. No exposure treatment adversely affected less than 50% of test organisms; therefore the EC50 concentration is less than the lowest Cu concentration.
 - b. Other than the control no exposure treatment adversely affected less than 50% of test organisms; estimated EC50s are based on Probit Analysis.
 - c. No exposure treatment adversely affected more than 50% of test organisms; therefore the EC50 concentration is greater than the highest Cu concentration and the WER is calculated using the > EC50 value.
 - d. Dissolved EC50 values were calculated using the 0.96 dissolved to total conversion factor at 0.96 from USEPA 2001 and 2007.
- Normalized EC50 = Normalized to a hardness of 100 mg CaCO3/L using hardness slope of 0.9422.
SMAV = Species mean acute value from USEPA 2001.
µg/L = micrograms per liter.

APPENDIX A: TABLE 21
 VERIFICATION CALCULATIONS OF DISSOLVED COPPER WERs THAT WERE CALCULATED FOR DAPHNIA MAGNA USING THE RECALCULATED SPECIES MEAN ACUTE VALUE IN THE WER DENOMINATOR

FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADUUM, NEW MEXICO
 SMELTER/TAILINGS SOILS IN SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Site Name (#) | STEO Site Water Cu EC50s | | | Measured EC50s from USEPA (2001) SMAV | | | Water Effect Ratios (WER) based on Tables 1 and 11 | | Verification of Dissolved Cu WERs based on Table 11 | |
|------------------------|--------------------------|------------------------|----------------|--|------------------------|----------------|--|-----------------------------|---|-----------|
| | Total Cu (µg/L) | Dissolved Cu (µg/L) | % Dissolved Cu | Total Cu (µg/L) | Dissolved Cu (µg/L) | % Dissolved Cu | WER SMAV Dissolved Cu WER | WER SMAV Total Cu WER | Dissolved WER | Total WER |
| | | | | | | | | | | |
| Round 1 Samples | | | | | | | | | | |
| WER 1-1 | 144.8 | 128.4 | 88.67% | 17.19 | 16.50 | 95.99% | 8.426 | 7.783 | | 7.783 |
| WER 1-2 | 107.8 | 103.0 | 95.52% | 17.19 | 16.50 | 95.99% | 6.272 | 6.242 | | 6.242 |
| WER 1-5 ^a | -- | -- | -- | 17.19 | 16.50 | 95.99% | -- | -- | | -- |
| WER 1-6 | 338.2 | 278.2 | 82.25% | 17.19 | 16.50 | 95.99% | 19.68 | 16.86 | | 16.86 |
| WER 1-7 | 111.7 | 91.09 | 81.55% | 17.19 | 16.50 | 95.99% | 6.498 | 5.521 | | 5.521 |
| WER 1-9 | 51.64 | 42.61 | 82.52% | 17.19 | 16.50 | 95.99% | 3.004 | 2.582 | | 2.582 |
| WER 1-10 | 57.01 | 54.15 | 94.99% | 17.19 | 16.50 | 95.99% | 3.316 | 3.282 | | 3.282 |
| WER 1-11 | 141.4 | 115.0 | 81.36% | 17.19 | 16.50 | 95.99% | 8.223 | 6.971 | | 6.971 |
| WER 1-12 | 23.08 | 19.09 | 82.73% | 17.19 | 16.50 | 95.99% | 1.343 | 1.157 | | 1.157 |
| WER 1-RCS | 75.39 | 63.21 | 83.85% | 17.19 | 16.50 | 95.99% | 4.385 | 3.831 | | 3.831 |
| WER D1-2 | 377.8 | 253.0 | 67.01% | 17.19 | 16.50 | 95.99% | 21.97 | 15.34 | | 15.34 |
| WER D2-1 ^b | 336.9 | 155.0 | 46.01% | 17.19 | 16.50 | 95.99% | 19.60 | 9.394 | | 9.394 |
| Round 2 Samples | | | | | | | | | | |
| WER 2-1 | 99.08 | 78.12 | 78.85% | 17.19 | 16.50 | 95.99% | 5.764 | 4.735 | | 4.735 |
| WER 2-6 ^c | 155.9 | 118.8 | 76.18% | 17.19 | 16.50 | 95.99% | 9.070 | 7.199 | | 7.199 |
| WER 2-9 ^d | >305.4 | >222.7 | 72.92% | 17.19 | 16.50 | 95.99% | >17.77 | >13.49 | | >13.50 |
| WER 2-11 | 190.5 | 133.0 | 69.84% | 17.19 | 16.50 | 95.99% | 11.08 | 8.063 | | 8.063 |
| WER 2-12 | 49.39 | 43.48 | 88.03% | 17.19 | 16.50 | 95.99% | 2.873 | 2.635 | | 2.635 |
| WER 2-D12 | 158.9 | 110.5 | 69.56% | 17.19 | 16.50 | 95.99% | 9.244 | 6.699 | | 6.699 |

Notes:

- a. No exposure treatment adversely affected less than 50% of test organisms; therefore the EC50 concentration is less than the lowest Cu concentration.
 - b. Other than the control no exposure treatment adversely affected less than 50% of test organisms; estimated EC50s are based on Probit Analysis.
 - c. No exposure treatment adversely affected more than 50% of test organisms; therefore the EC50 concentration is greater than the highest Cu concentration and the WER is calculated using the > EC50 value.
 - d. Dissolved EC50 values were calculated using the 0.96 dissolved to total conversion factor at 0.96 from USEPA 2001 and 2007.
- Normalized EC50 = Normalized to a hardness of 100 mg CaCO3/L using hardness slope of 0.9422.
 SMAV = Species mean acute value - only the measured EC50 values from USEPA 2001.
 µg/L = micrograms per liter.

APPENDIX A: TABLE 22

VERIFICATION CALCULATIONS OF DISSOLVED COPPER WERs THAT WERE CALCULATED FOR DAPHNIA MAGNA USING THE GEOMETRIC MEAN OF LABORATORY WATER EC50s IN THE WER DENOMINATOR

FREEMPORT-MCMORAN CHINO MINES COMPANY
VANADUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Site Water ID | SITEIU Site Water Cu EC50s | | | Geometric Mean of 11 Lab Water Normalized EC50 | | | Water Effect Ratios (WER) listed in Tables 17 and 18 | | Verification of Dissolved Cu WERs based on Total Cu | |
|------------------------|----------------------------|---------------------|----------------|--|---------------------|----------------|--|------------------|--|--|
| | Total Cu (pp/L) | Dissolved Cu (pp/L) | % Dissolved Cu | Total Cu (pp/L) | Dissolved Cu (pp/L) | % Dissolved Cu | WER = Site Water EC50 (data number) | | Dissolved WER = Dissolved Cu (pp/L) / (EC50) (data number) | Total WER = Total Cu (pp/L) / (EC50) (data number) |
| | | | | | | | GEOMETRIC MEAN (data number) | | | |
| | | | | | | | Total Cu WER | Dissolved Cu WER | | |
| Round 1 Samples | | | | | | | | | | |
| WER 1-1 | 144.8 | 128.4 | 88.67% | 14.54 | 13.96 | 96.01% | 9.962 | 9.200 | 9.200 | |
| WER 1-2 | 107.8 | 103.0 | 95.52% | 14.54 | 13.96 | 96.01% | 7.416 | 7.376 | 7.376 | |
| WER 1-5 ^a | - | - | - | 14.54 | 13.96 | 96.01% | - | - | - | |
| WER 1-6 | 338.2 | 278.2 | 82.25% | 14.54 | 13.96 | 96.01% | 23.26 | 19.93 | 19.93 | |
| WER 1-7 | 111.7 | 91.09 | 81.55% | 14.54 | 13.96 | 96.01% | 7.682 | 6.525 | 6.525 | |
| WER 1-9 | 51.64 | 42.61 | 82.52% | 14.54 | 13.96 | 96.01% | 3.551 | 3.052 | 3.052 | |
| WER 1-10 | 57.01 | 54.15 | 94.99% | 14.54 | 13.96 | 96.01% | 3.921 | 3.870 | 3.870 | |
| WER 1-11 | 141.4 | 115.0 | 81.36% | 14.54 | 13.96 | 96.01% | 9.722 | 8.239 | 8.239 | |
| WER 1-12 | 23.08 | 19.09 | 82.73% | 14.54 | 13.96 | 96.01% | 1.587 | 1.368 | 1.368 | |
| WER 1-RCS | 75.39 | 63.21 | 83.85% | 14.54 | 13.96 | 96.01% | 5.185 | 4.528 | 4.528 | |
| WER D1-2 | 377.6 | 253.0 | 67.01% | 14.54 | 13.96 | 96.01% | 25.97 | 18.13 | 18.13 | |
| WER D2-1 ^b | 336.9 | 155.0 | 46.01% | 14.54 | 13.96 | 96.01% | 23.17 | 11.10 | 11.10 | |
| Round 2 Samples | | | | | | | | | | |
| WER 2-1 | 99.08 | 78.12 | 78.85% | 14.54 | 13.96 | 96.01% | 6.814 | 5.596 | 5.596 | |
| WER 2-6 ^c | 155.9 | 118.8 | 76.18% | 14.54 | 13.96 | 96.01% | 10.72 | 8.508 | 8.508 | |
| WER 2-9 ^d | >305.4 | >222.7 | 72.92% | 14.54 | 13.96 | 96.01% | >21.01 | >15.95 | >15.95 | |
| WER 2-11 | 190.5 | 133.0 | 69.84% | 14.54 | 13.96 | 96.01% | 13.10 | 9.530 | 9.530 | |
| WER 2-12 | 49.39 | 43.48 | 88.03% | 14.54 | 13.96 | 96.01% | 3.397 | 3.114 | 3.114 | |
| WER 2-D12 | 158.9 | 110.5 | 69.56% | 14.54 | 13.96 | 96.01% | 10.93 | 7.918 | 7.918 | |

Notes:

- a. No exposure treatment adversely affected less than 50% of test organisms; therefore the EC50 concentration is less than the lowest Cu concentration.
 - b. Other than the control no exposure treatment adversely affected less than 50% of test organisms; estimated EC50s are based on Probit Analysis.
 - c. No exposure treatment adversely affected more than 50% of test organisms; therefore the EC50 concentration is greater than the highest Cu concentration and the WER is calculated using the > EC50 value.
 - d. Dissolved EC50 values were calculated using the 0.96 dissolved to total conversion factor at 0.96 from USEPA 2001 and 2007
- Normalized EC50 = Normalized to a hardness of 100 mg CaCO3/L using hardness slope of 0.9422.
- Geometric Mean = Geometric mean of the 11 normalized laboratory water copper LC50 values conducted side-by-side with site water toxicity.
- µg/L = micrograms per liter.

**APPENDIX A: TABLE 23
SUMMARY QA/QC FIELD SAMPLES COLLECTED DURING THE WER SAMPLING PROGRAM**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Parameters | Round 1 | | | | Round 2 | | | |
|---|----------|--------------------|---------------|---------------------|----------|--------------------|-------------------|---------------------|
| | WER-MC-1 | WER-MC-1 Duplicate | WER-1-Blank-1 | WER-1-Bottled Blank | WER-2-11 | WER-2-11 Duplicate | WER-2-Field Blank | WER-2-Bottled Blank |
| Major Cations (mg/L) | | | | | | | | |
| Calcium, dissolved | 23.5 | 23.9 | <0.2 | <0.2 | 25.6 | 25.5 | <0.2 | <0.2 |
| Calcium, total | 25.4 | 25.4 | <0.2 | <0.2 | 26.7 | 27.2 | <0.2 | <0.2 |
| Magnesium, dissolved | 11.3 | 11.5 | <0.2 | <0.2 | 13.3 | 13.3 | <0.2 | <0.2 |
| Magnesium, total | 12.1 | 12 | <0.2 | <0.2 | 14.1 | 14.4 | <0.2 | <0.2 |
| Potassium, dissolved | 3.1 | 3.2 | <0.3 | <0.3 | 5.2 | 5.2 | <0.3 | <0.3 |
| Sodium, dissolved | 12.5 | 12.5 | <0.3 | <0.3 | 7.8 | 7.7 | 2.6 | 2.5 |
| Metals (µg/L) | | | | | | | | |
| Aluminum, dissolved | 2 | 6 | <1 | <1 | 10 | 9 | <1 | <1 |
| Aluminum, total | 40 | 21 | 14 | 9 | 1260 | 1240 | 6 | 5 |
| Cadmium, dissolved | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Cadmium, total | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Copper, dissolved | 8.1 | 8.1 | <0.5 | <0.5 | 7.9 | 7.5 | <0.5 | <0.5 |
| Copper, total | 8.5 | 8.4 | <0.5 | <0.5 | 10.7 | 10.6 | <0.5 | <0.5 |
| Iron, dissolved | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 |
| Iron, total | <20 | <20 | <20 | <20 | 890 | 930 | <20 | <20 |
| Lead, dissolved | <0.1 | <0.1 | <0.1 | <0.1 | 0.2 | <0.1 | <0.1 | <0.1 |
| Lead, total | <0.1 | <0.1 | <0.1 | <0.1 | 0.3 | 0.3 | <0.1 | <0.1 |
| Manganese, dissolved | 16.6 | 19.6 | <0.5 | <0.5 | 30.8 | 35.2 | <0.5 | <0.5 |
| Manganese, total | 37.6 | 37.4 | <0.5 | <0.5 | 113.6 | 107.1 | <0.5 | <0.5 |
| Zinc, dissolved | <2 | 5 | <2 | <2 | 5 | 2 | <2 | <2 |
| Zinc, total | 3 | <2 | 2 | 3 | 4 | 3 | <2 | <2 |
| Wet Chemistry | | | | | | | | |
| Bicarbonate as CaCO ₃ (mg/L) | 106 | 106 | <2 | <2 | 102 | 102 | 3 | <2 |
| Dissolved inorganic carbon (mg/L) | - | - | - | - | 28.6 | 28.9 | <1 | <1 |
| Dissolved organic carbon (DOC) (mg/L) | 3.9 | 5.3 | <1 | <1 | 12.3 | 12.8 | <1 | <1 |
| Total inorganic carbon (mg/L) | - | - | - | - | 27.5 | 28.1 | <1 | <1 |
| Total organic carbon (TOC) (mg/L) | 4.8 | 5.1 | <1 | <1 | 13.5 | 14.3 | <1 | <1 |
| Carbonate as CaCO ₃ (mg/L) | <2 | 2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Cation-Anion Balance % | 1.9 | 1.9 | 0 | 0 | 3.7 | 3.7 | 0 | 0 |
| Chloride (mg/L) | 4 | 4 | <1 | <1 | 6 | 6 | 2 | 2 |
| Hardness as CaCO ₃ (mg/L) | 105 | 107 | <1 | <1 | 119 | 118 | <1 | <1 |
| Hydroxide as CaCO ₃ (mg/L) | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| pH ¹ | 8.3 | 8.3 | 6.1 | 5.7 | 8.1 | 8.1 | 6.9 | 6.7 |
| Total dissolved solids (TDS) (mg/L) | 180 | 180 | <10 | <10 | 190 | 190 | <10 | <10 |
| Total suspended solids (TSS) (mg/L) | 5 | <5 | <5 | <5 | 6 | 7 | <5 | <5 |
| Sulfate (mg/L) | 20 | 19 | 1 | <1 | 22.5 | 22.5 | <0.5 | <0.5 |
| Sum of Anions (meq/L) | 2.6 | 2.6 | <0.1 | 0 | 2.6 | 2.6 | 0.1 | <0.1 |
| Sum of Cations (meq/L) | 2.7 | 2.7 | <0.1 | <0.1 | 2.8 | 2.8 | 0.1 | 0.1 |
| TDS (calculated) (mg/L) | 138 | 140 | <10 | <10 | 142 | 141 | <10 | <10 |
| TDS (ratio - measured/calculated) | 1.3 | 1.29 | 0 | 0 | 1.34 | 1.35 | 0 | 0 |
| Total Alkalinity (mg/L) | 108 | 108 | <2 | <2 | 102 | 102 | 3 | <2 |

Notes:

¹ Analysis exceeded method hold time. pH is a field test with no hold time.

Bolded values- analyte concentration detected at a value between a MDL and PQL. The associated value is an estimated quantity.

< values - the material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantification limit or the sample detection limit.

mg/L = milligrams per liter.

µg/L = micrograms per liter.

meq/L = milliequivalents per liter.



Appendix B

Pearson Product Moment Correlation Statistical Summary

APPENDIX B
PEARSON PRODUCT MOMENT CORRELATION SUMMARY
FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Pearson Product Moment Correlation

Data source: Interim Criteria Adjustment Report ARCADIS 2013 (all input variables log-transformed except pH)

Cell Contents:
Correlation Coefficient
P Value
Number of Samples

| | log TOC | log DOC | log (H/A) | pH | Log TDS+TSS | log TDS |
|-------------|-------------------------|---------------------------|--------------------------|------------------------|------------------------|---------------------------|
| Log LC50 | 0.789 0.000165 17 | 0.866 0.00000685 17 | -0.734 0.000787 17 | -0.314 0.220 17 | 0.494 0.0440 17 | 0.495 0.0433 17 |
| log TOC | | 0.895 0.00000120 17 | -0.476 0.0536 17 | -0.398 0.114 17 | 0.194 0.456 17 | 0.191 0.463 17 |
| log DOC | | | -0.678 0.00281 17 | -0.488 0.0471 17 | 0.236 0.361 17 | 0.234 0.366 17 |
| log (H/A) | | | | 0.150 0.564 17 | -0.241 0.352 17 | -0.248 0.338 17 |
| pH | | | | | 0.00996 0.970 17 | 0.0183 0.945 17 |
| Log TDS+TSS | | | | | | 0.999 1.535E-020 17 |

APPENDIX B
PEARSON PRODUCT MOMENT CORRELATION SUMMARY
FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| | Log TSS | log Hardness | log Alkalinity | Log Ca | Log Mg | Log K |
|----------------|------------------------|---------------------------|--------------------------|----------------------------|-------------------------------|-----------------------|
| Log LC50 | 0.266 0.301 17 | 0.320 0.211 17 | 0.655 0.00436 17 | 0.399 0.112 17 | 0.342 0.179 17 | 0.567 0.0175 17 |
| log TOC | 0.144 0.580 17 | 0.0491 0.852 17 | 0.309 0.228 17 | 0.112 0.668 17 | 0.0844 0.747 17 | 0.415 0.0978 17 |
| log DOC | 0.187 0.472 17 | 0.0404 0.878 17 | 0.418 0.0948 17 | 0.121 0.643 17 | 0.0569 0.828 17 | 0.370 0.144 17 |
| log (H/A) | -0.0608 0.817 17 | -0.166 0.524 17 | -0.695 0.00196 17 | -0.224 0.388 17 | -0.183 0.482 17 | -0.365 0.150 17 |
| pH | -0.0738 0.778 17 | 0.162 0.535 17 | 0.0316 0.904 17 | 0.180 0.489 17 | 0.177 0.496 17 | 0.151 0.562 17 |
| Log TDS+TSS | 0.496 0.0429 17 | 0.875 0.00000429 17 | 0.776 0.000249 17 | 0.916 0.000000251 17 | 0.795 0.000137 17 | 0.443 0.0750 17 |
| log TDS | 0.450 0.0697 17 | 0.879 0.00000339 17 | 0.783 0.000201 17 | 0.922 0.000000143 17 | 0.797 0.000127 17 | 0.426 0.0879 17 |
| Log TSS | | 0.354 0.163 17 | 0.293 0.254 17 | 0.347 0.172 17 | 0.378 0.135 17 | 0.580 0.0147 17 |
| log Hardness | | | 0.825 0.0000467 17 | 0.980 6.028E-012 17 | 0.965 0.000000000380 17 | 0.430 0.0848 17 |
| log Alkalinity | | | | 0.843 0.0000214 17 | 0.809 0.0000841 17 | 0.523 0.0312 17 |
| Log Ca | | | | | 0.931 0.0000000584 17 | 0.447 0.0721 17 |
| Log Mg | | | | | | 0.572 0.0164 17 |

APPENDIX B
PEARSON PRODUCT MOMENT CORRELATION SUMMARY
FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| | Log Na | Log SO4 | Log Fe | Log TR Fe | Log Al | Log TR Al |
|----------------|----------|----------|---------|-----------|----------|-----------|
| Log LC50 | 0.392 | -0.423 | 0.392 | 0.524 | 0.356 | 0.303 |
| | 0.120 | 0.0909 | 0.120 | 0.0310 | 0.161 | 0.238 |
| | 17 | 17 | 17 | 17 | 17 | 17 |
| log TOC | 0.0857 | -0.344 | 0.450 | 0.600 | 0.301 | 0.250 |
| | 0.744 | 0.177 | 0.0700 | 0.0109 | 0.241 | 0.332 |
| | 17 | 17 | 17 | 17 | 17 | 17 |
| log DOC | 0.218 | -0.400 | 0.418 | 0.698 | 0.189 | 0.389 |
| | 0.401 | 0.112 | 0.0954 | 0.00183 | 0.468 | 0.123 |
| | 17 | 17 | 17 | 17 | 17 | 17 |
| log (H/A) | -0.396 | 0.744 | -0.328 | -0.431 | -0.0769 | -0.308 |
| | 0.115 | 0.000613 | 0.199 | 0.0843 | 0.769 | 0.229 |
| | 17 | 17 | 17 | 17 | 17 | 17 |
| pH | 0.0322 | -0.0325 | -0.240 | -0.323 | -0.174 | -0.150 |
| | 0.902 | 0.902 | 0.354 | 0.205 | 0.505 | 0.565 |
| | 17 | 17 | 17 | 17 | 17 | 17 |
| Log TDS+TSS | 0.701 | 0.249 | -0.269 | -0.0306 | 0.0632 | 0.0496 |
| | 0.00173 | 0.335 | 0.296 | 0.907 | 0.810 | 0.850 |
| | 17 | 17 | 17 | 17 | 17 | 17 |
| log TDS | 0.719 | 0.250 | -0.258 | -0.0450 | 0.0600 | 0.0251 |
| | 0.00114 | 0.333 | 0.317 | 0.864 | 0.819 | 0.924 |
| | 17 | 17 | 17 | 17 | 17 | 17 |
| Log TSS | -0.00711 | 0.0384 | -0.311 | 0.286 | 0.126 | 0.509 |
| | 0.978 | 0.884 | 0.224 | 0.266 | 0.631 | 0.0367 |
| | 17 | 17 | 17 | 17 | 17 | 17 |
| log Hardness | 0.486 | 0.234 | -0.500 | -0.342 | -0.0640 | -0.216 |
| | 0.0479 | 0.366 | 0.0408 | 0.180 | 0.807 | 0.405 |
| | 17 | 17 | 17 | 17 | 17 | 17 |
| log Alkalinity | 0.582 | -0.256 | -0.177 | -0.00191 | -0.00253 | 0.0194 |
| | 0.0143 | 0.320 | 0.498 | 0.994 | 0.992 | 0.941 |
| | 17 | 17 | 17 | 17 | 17 | 17 |
| Log Ca | 0.577 | 0.231 | -0.420 | -0.217 | -0.0163 | -0.128 |
| | 0.0154 | 0.372 | 0.0936 | 0.403 | 0.951 | 0.624 |
| | 17 | 17 | 17 | 17 | 17 | 17 |
| Log Mg | 0.300 | 0.118 | -0.521 | -0.294 | 0.0148 | -0.147 |
| | 0.243 | 0.651 | 0.0320 | 0.252 | 0.955 | 0.575 |
| | 17 | 17 | 17 | 17 | 17 | 17 |
| Log K | -0.109 | -0.420 | -0.0676 | 0.360 | 0.454 | 0.431 |
| | 0.678 | 0.0930 | 0.797 | 0.156 | 0.0675 | 0.0839 |
| | 17 | 17 | 17 | 17 | 17 | 17 |

APPENDIX B
PEARSON PRODUCT MOMENT CORRELATION SUMMARY
FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
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| | Log SO4 | Log Fe | Log TR Fe | Log Al | Log TR Al |
|-----------|----------------------|-----------------------|------------------------|-----------------------|--------------------------|
| Log Na | 0.149 0.569 17 | 0.120 0.647 17 | -0.0407 0.877 17 | -0.144 0.580 17 | -0.109 0.676 17 |
| Log SO4 | | -0.410 0.103 17 | -0.402 0.109 17 | -0.329 0.197 17 | -0.375 0.138 17 |
| Log Fe | | | 0.523 0.0313 17 | 0.409 0.103 17 | 0.238 0.357 17 |
| Log TR Fe | | | | 0.443 0.0748 17 | 0.852 0.0000142 17 |
| Log Al | | | | | 0.517 0.0337 17 |
| Log TR Al | | | | | |

The pair(s) of variables with positive correlation coefficients and P values below 0.050 tend to increase together. For the pairs with negative correlation coefficients and P values below 0.050, one variable tends to decrease while the other increases. For pairs with P values greater than 0.050, there is no significant relationship between the two variables.



Appendix C

Statistical Summaries of Univariate Linear Regression Analyses

APPENDIX C
 STATISTICAL SUMMARIES OF SINGLE LINEAR REGRESSION ANALYSES
 FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS 2013 (all variables log transformed)

Log LC50 = 0.965 + (0.489 * log Hardness)

N = 17

R = 0.320 Rsqr = 0.102 Adj Rsqr = 0.0423

Standard Error of Estimate = 0.298

| | Coefficient | Std. Error | t | P |
|--------------|--------------------|-------------------|----------|----------|
| Constant | 0.965 | 0.717 | 1.345 | 0.198 |
| log Hardness | 0.489 | 0.374 | 1.307 | 0.211 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|-----------|-----------|-----------|----------|----------|
| Regression | 1 | 0.151 | 0.151 | 1.707 | 0.211 |
| Residual | 15 | 1.331 | 0.0887 | | |
| Total | 16 | 1.482 | 0.0926 | | |

Normality Test (Shapiro-Wilk) Passed (P = 0.160)

Constant Variance Test: Passed (P = 0.393)

Power of performed test with alpha = 0.050: 0.236

The power of the performed test (0.236) is below the desired power of 0.800.
 Less than desired power indicates you are less likely to detect a difference when one actually exists.
 Negative results should be interpreted cautiously.

APPENDIX C
 STATISTICAL SUMMARIES OF SINGLE LINEAR REGRESSION ANALYSES
 FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS 2013 (all variables log transformed)

Log LC50 = 0.571 + (0.730 * log Alkalinity)

N = 17

R = 0.655 Rsqr = 0.428 Adj Rsqr = 0.390

Standard Error of Estimate = 0.238

| | Coefficient | Std. Error | t | P |
|----------------|--------------------|-------------------|----------|----------|
| Constant | 0.571 | 0.400 | 1.427 | 0.174 |
| log Alkalinity | 0.730 | 0.218 | 3.353 | 0.004 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|-----------|-----------|-----------|----------|----------|
| Regression | 1 | 0.635 | 0.635 | 11.243 | 0.004 |
| Residual | 15 | 0.847 | 0.0565 | | |
| Total | 16 | 1.482 | 0.0926 | | |

Normality Test (Shapiro-Wilk) Passed (P = 0.661)

Constant Variance Test: Passed (P = 0.341)

Power of performed test with alpha = 0.050: 0.834

APPENDIX C
 STATISTICAL SUMMARIES OF SINGLE LINEAR REGRESSION ANALYSES
 FREEPORT-MCMORAN CHINO MINES COMPANY
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Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS 2013 (all variables log transformed)

$$\text{Log LC50} = 2.026 - (1.428 * \log (H/A))$$

N = 17

R = 0.734 Rsqr = 0.539 Adj Rsqr = 0.509

Standard Error of Estimate = 0.213

| | Coefficient | Std. Error | t | P |
|-----------|--------------------|-------------------|----------|----------|
| Constant | 2.026 | 0.0602 | 33.685 | <0.001 |
| log (H/A) | -1.428 | 0.341 | -4.191 | <0.001 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|-----------|-----------|-----------|----------|----------|
| Regression | 1 | 0.799 | 0.799 | 17.565 | <0.001 |
| Residual | 15 | 0.683 | 0.0455 | | |
| Total | 16 | 1.482 | 0.0926 | | |

Normality Test (Shapiro-Wilk) Passed (P = 0.476)

Constant Variance Test: Passed (P = 0.824)

Power of performed test with alpha = 0.050: 0.940

APPENDIX C
 STATISTICAL SUMMARIES OF SINGLE LINEAR REGRESSION ANALYSES
 FREEPORT-MCMORAN CHINO MINES COMPANY
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Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS 2013

Lab Hardness = 22.494 + (0.850 * Alkalinity)

N = 17

R = 0.929 Rsqr = 0.864 Adj Rsqr = 0.855

Standard Error of Estimate = 19.945

| | Coefficient | Std. Error | t | P |
|------------|--------------------|-------------------|----------|----------|
| Constant | 22.494 | 8.472 | 2.655 | 0.018 |
| Alkalinity | 0.850 | 0.0871 | 9.756 | <0.001 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|-----------|-----------|-----------|----------|----------|
| Regression | 1 | 37866.751 | 37866.751 | 95.188 | <0.001 |
| Residual | 15 | 5967.132 | 397.809 | | |
| Total | 16 | 43833.882 | 2739.618 | | |

Normality Test (Shapiro-Wilk) Passed (P = 0.242)

Constant Variance Test: Passed (P = 0.646)

Power of performed test with alpha = 0.050: 1.000

APPENDIX C
 STATISTICAL SUMMARIES OF SINGLE LINEAR REGRESSION ANALYSES
 FREEPORT-MCMORAN CHINO MINES COMPANY
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Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS 2013 (all variables log transformed)

Log LC50 = 1.183 + (0.848 * log DOC)

N = 17

R = 0.866 Rsqr = 0.751 Adj Rsqr = 0.734

Standard Error of Estimate = 0.157

| | Coefficient | Std. Error | t | P |
|----------|--------------------|-------------------|----------|----------|
| Constant | 1.183 | 0.113 | 10.485 | <0.001 |
| log DOC | 0.848 | 0.126 | 6.721 | <0.001 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|-----------|-----------|-----------|----------|----------|
| Regression | 1 | 1.113 | 1.113 | 45.172 | <0.001 |
| Residual | 15 | 0.369 | 0.0246 | | |
| Total | 16 | 1.482 | 0.0926 | | |

Normality Test (Shapiro-Wilk) Passed (P = 0.604)

Constant Variance Test: Passed (P = 0.928)

Power of performed test with alpha = 0.050: 0.999

APPENDIX C
 STATISTICAL SUMMARIES OF SINGLE LINEAR REGRESSION ANALYSES
 FREEPORT-MCMORAN CHINO MINES COMPANY
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Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS 2013 (all variables log transformed)

Log LC50 = 0.977 + (1.025 * log TOC)

N = 17

R = 0.789 Rsqr = 0.623 Adj Rsqr = 0.598

Standard Error of Estimate = 0.193

| | Coefficient | Std. Error | t | P |
|----------|--------------------|-------------------|----------|----------|
| Constant | 0.977 | 0.191 | 5.126 | <0.001 |
| log TOC | 1.025 | 0.206 | 4.978 | <0.001 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|-----------|-----------|-----------|----------|----------|
| Regression | 1 | 0.923 | 0.923 | 24.777 | <0.001 |
| Residual | 15 | 0.559 | 0.0373 | | |
| Total | 16 | 1.482 | 0.0926 | | |

Normality Test (Shapiro-Wilk) Passed (P = 0.342)

Constant Variance Test: Passed (P = 0.234)

Power of performed test with alpha = 0.050: 0.979

APPENDIX C
 STATISTICAL SUMMARIES OF SINGLE LINEAR REGRESSION ANALYSES
 FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
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Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS 2013

Log LC50 = 3.394 - (0.186 * pH)

N = 17

R = 0.314 Rsqr = 0.0985 Adj Rsqr = 0.0385

Standard Error of Estimate = 0.298

| | Coefficient | Std. Error | t | P |
|----------|--------------------|-------------------|----------|----------|
| Constant | 3.394 | 1.171 | 2.899 | 0.011 |
| pH | -0.186 | 0.145 | -1.281 | 0.220 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|-----------|-----------|-----------|----------|----------|
| Regression | 1 | 0.146 | 0.146 | 1.640 | 0.220 |
| Residual | 15 | 1.336 | 0.0891 | | |
| Total | 16 | 1.482 | 0.0926 | | |

Normality Test (Shapiro-Wilk) Passed (P = 0.496)

Constant Variance Test: Passed (P = 0.179)

Power of performed test with alpha = 0.050: 0.228

The power of the performed test (0.228) is below the desired power of 0.800.
 Less than desired power indicates you are less likely to detect a difference when one actually exists.
 Negative results should be interpreted cautiously.



Appendix D

Statistical Summaries of Multiple Linear Regression Analyses

APPENDIX D
STATISTICAL SUMMARIES OF MULTIPLE LINEAR REGRESSION ANALYSES
FREEMPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = -0.128 + (0.703 * \log \text{TOC}) - (0.787 * \log (\text{H/A})) + (0.653 * \log \text{TDS})$$

N = 17

R = 0.932 Rsq = 0.869 Adj Rsq = 0.838

Standard Error of Estimate = 0.122

| | Coefficient | Std. Error | t | P | VIF |
|-----------|--------------------|-------------------|----------|----------|------------|
| Constant | -0.128 | 0.536 | -0.238 | 0.815 | |
| log TOC | 0.703 | 0.149 | 4.718 | <0.001 | 1.302 |
| log (H/A) | -0.787 | 0.226 | -3.485 | 0.004 | 1.336 |
| log TDS | 0.653 | 0.233 | 2.800 | 0.015 | 1.073 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|-----------|-----------|-----------|----------|----------|
| Regression | 3 | 1.288 | 0.429 | 28.669 | <0.001 |
| Residual | 13 | 0.195 | 0.0150 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SS Incr | SS Marg |
|---------------|----------------|----------------|
| log TOC | 0.923 | 0.333 |
| log (H/A) | 0.247 | 0.182 |
| log TDS | 0.117 | 0.117 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|-----------|----------|
| log TOC | <0.001 |
| log (H/A) | 0.004 |
| log TDS | 0.015 |

All independent variables appear to contribute to predicting Log LC50 (P < 0.05).

Normality Test (Shapiro-Wilk) Passed (P = 0.614)

Constant Variance Test: Passed (P = 0.246)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFBETIS |
|------------|---------------------|-----------------|----------------|
| 1 | 0.0448 | 0.204 | -0.418 |
| 2 | 0.00392 | 0.0853 | 0.121 |
| 3 | 0.0430 | 0.270 | 0.406 |
| 4 | 0.0227 | 0.0841 | 0.301 |
| 5 | 0.324 | 0.234 | 1.334 |
| 6 | 0.0855 | 0.130 | 0.619 |
| 7 | 0.124 | 0.416 | -0.694 |
| 8 | 0.683 | 0.608 | 1.709 |
| 9 | 0.00499 | 0.177 | -0.136 |
| 10 | 0.244 | 0.429 | -1.001 |
| 11 | 0.0368 | 0.387 | 0.372 |
| 12 | 0.0714 | 0.0976 | -0.575 |
| 13 | 0.0291 | 0.146 | -0.336 |
| 14 | 0.0219 | 0.143 | -0.290 |
| 15 | 0.000491 | 0.179 | -0.0426 |
| 16 | 0.00325 | 0.124 | -0.110 |
| 17 | 0.0334 | 0.286 | -0.356 |

APPENDIX D
 STATISTICAL SUMMARIES OF MULTIPLE LINEAR REGRESSION ANALYSES
 FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = -0.0439 + (0.633 * \log \text{DOC}) - (0.438 * \log (\text{H/A})) + (0.645 * \log \text{TDS})$$

N = 17

R = 0.932 Rsqr = 0.868 Adj Rsqr = 0.838

Standard Error of Estimate = 0.123

| | Coefficient | Std. Error | t | P | VIF |
|-----------|-------------|------------|---------|--------|-------|
| Constant | -0.0439 | 0.534 | -0.0822 | 0.936 | |
| log DOC | 0.633 | 0.135 | 4.701 | <0.001 | 1.865 |
| log (H/A) | -0.438 | 0.268 | -1.631 | 0.127 | 1.878 |
| log TDS | 0.645 | 0.234 | 2.759 | 0.016 | 1.075 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|----|-------|--------|--------|--------|
| Regression | 3 | 1.287 | 0.429 | 28.522 | <0.001 |
| Residual | 13 | 0.195 | 0.0150 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SSIncr | SSMarg |
|-----------|--------|--------|
| log DOC | 1.113 | 0.332 |
| log (H/A) | 0.0595 | 0.0400 |
| log TDS | 0.114 | 0.114 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|-----------|--------|
| log DOC | <0.001 |
| log (H/A) | 0.127 |
| log TDS | 0.016 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified).
 The following appear to account for the ability to predict Log LC50 (P < 0.05): log DOC, log TDS

Normality Test (Shapiro-Wilk) Passed (P = 0.338)

Constant Variance Test: Passed (P = 0.387)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFFITs |
|-----|--------------|----------|---------|
| 1 | 0.000278 | 0.105 | 0.0321 |
| 2 | 0.0000149 | 0.0991 | 0.00235 |
| 3 | 0.0796 | 0.281 | 0.560 |
| 4 | 0.00431 | 0.0816 | 0.127 |
| 5 | 0.325 | 0.228 | 1.348 |
| 6 | 0.0128 | 0.173 | 0.220 |
| 7 | 0.0479 | 0.497 | -0.424 |
| 8 | 0.404 | 0.586 | 1.279 |
| 9 | 0.00364 | 0.175 | -0.116 |
| 10 | 0.0590 | 0.483 | -0.471 |
| 11 | 0.0288 | 0.383 | 0.329 |
| 12 | 0.0709 | 0.0976 | -0.573 |
| 13 | 0.117 | 0.192 | -0.714 |
| 14 | 0.0994 | 0.101 | -0.710 |
| 15 | 0.0304 | 0.147 | 0.345 |
| 16 | 0.000182 | 0.101 | 0.0259 |
| 17 | 0.000142 | 0.269 | 0.0229 |

APPENDIX D
STATISTICAL SUMMARIES OF MULTIPLE LINEAR REGRESSION ANALYSES
FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = 0.122 + (0.674 * \log \text{TOC}) - (0.790 * \log (\text{H/A})) + (0.663 * \log \text{TDS}) - (0.0308 * \text{pH})$$

N = 17

R = 0.933 Rsq = 0.871 Adj Rsq = 0.828

Standard Error of Estimate = 0.126

| | Coefficient | Std. Error | t | P | VIF |
|-----------|--------------------|-------------------|----------|----------|------------|
| Constant | 0.122 | 0.778 | 0.157 | 0.878 | |
| log TOC | 0.674 | 0.166 | 4.051 | 0.002 | 1.524 |
| log (H/A) | -0.790 | 0.233 | -3.390 | 0.005 | 1.338 |
| log TDS | 0.663 | 0.242 | 2.746 | 0.018 | 1.083 |
| pH | -0.0308 | 0.0674 | -0.458 | 0.655 | 1.202 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|-----------|-----------|-----------|----------|----------|
| Regression | 4 | 1.291 | 0.323 | 20.246 | <0.001 |
| Residual | 12 | 0.191 | 0.0159 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SS Inr | SS Marg |
|---------------|---------------|----------------|
| log TOC | 0.923 | 0.262 |
| log (H/A) | 0.247 | 0.183 |
| log TDS | 0.117 | 0.120 |
| pH | 0.00334 | 0.00334 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|-----------|----------|
| log TOC | 0.002 |
| log (H/A) | 0.005 |
| log TDS | 0.018 |
| pH | 0.655 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified).

The following appear to account for the ability to predict Log LC50 (P < 0.05): log TOC, log (H/A), log TDS

Normality Test (Shapiro-Wilk) Passed (P = 0.659)

Constant Variance Test: Passed (P = 0.316)

Power of performed test with alpha = 0.05: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFBETIS |
|------------|---------------------|-----------------|----------------|
| 1 | 0.0319 | 0.219 | -0.392 |
| 2 | 0.00307 | 0.182 | 0.119 |
| 3 | 0.0346 | 0.272 | 0.406 |
| 4 | 0.0174 | 0.0843 | 0.294 |
| 5 | 0.248 | 0.244 | 1.292 |
| 6 | 0.0663 | 0.141 | 0.605 |
| 7 | 0.150 | 0.453 | -0.863 |
| 8 | 0.497 | 0.609 | 1.621 |
| 9 | 0.00225 | 0.214 | -0.102 |
| 10 | 0.525 | 0.692 | -1.632 |
| 11 | 0.0720 | 0.454 | 0.585 |
| 12 | 0.0612 | 0.116 | -0.590 |
| 13 | 0.109 | 0.308 | -0.746 |
| 14 | 0.0265 | 0.172 | -0.358 |
| 15 | 0.000541 | 0.289 | 0.0498 |
| 16 | 0.00198 | 0.130 | -0.0955 |
| 17 | 0.104 | 0.422 | -0.711 |

APPENDIX D
 STATISTICAL SUMMARIES OF MULTIPLE LINEAR REGRESSION ANALYSES
 FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

Log LC50 = -0.254 + (0.664 * log DOC) - (0.411 * log (H/A)) + (0.634 * log TDS) + (0.0256 * pH)

N = 17

R = 0.932 Rsqr = 0.869 Adj Rsqr = 0.826

Standard Error of Estimate = 0.127

| | Coefficient | Std. Error | t | P | VIF |
|-----------|-------------|------------|--------|-------|-------|
| Constant | -0.254 | 0.824 | -0.309 | 0.763 | |
| log DOC | 0.664 | 0.166 | 4.009 | 0.002 | 2.628 |
| log (H/A) | -0.411 | 0.288 | -1.426 | 0.179 | 2.021 |
| log TDS | 0.634 | 0.244 | 2.598 | 0.023 | 1.092 |
| pH | 0.0256 | 0.0744 | 0.344 | 0.736 | 1.447 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|----|-------|--------|--------|--------|
| Regression | 4 | 1.289 | 0.322 | 19.971 | <0.001 |
| Residual | 12 | 0.194 | 0.0161 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SS In cr | SS Marg |
|-----------|----------|---------|
| log DOC | 1.113 | 0.259 |
| log (H/A) | 0.0595 | 0.0328 |
| log TDS | 0.114 | 0.109 |
| pH | 0.00191 | 0.00191 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|-----------|-------|
| log DOC | 0.002 |
| log (H/A) | 0.179 |
| log TDS | 0.023 |
| pH | 0.736 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified).
 The following appear to account for the ability to predict Log LC50 (P < 0.05): log DOC, log TDS

Normality Test (Shapiro-Wilk) Passed (P = 0.363)

Constant Variance Test: Passed (P = 0.566)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFBETIS |
|-----|--------------|----------|---------|
| 1 | 0.0000973 | 0.113 | 0.0211 |
| 2 | 0.000564 | 0.178 | 0.0509 |
| 3 | 0.0597 | 0.281 | 0.541 |
| 4 | 0.00305 | 0.0872 | 0.119 |
| 5 | 0.253 | 0.231 | 1.337 |
| 6 | 0.00930 | 0.174 | 0.208 |
| 7 | 0.0283 | 0.625 | -0.361 |
| 8 | 0.348 | 0.594 | 1.331 |
| 9 | 0.00764 | 0.231 | -0.188 |
| 10 | 0.374 | 0.692 | -1.357 |
| 11 | 0.0168 | 0.447 | 0.279 |
| 12 | 0.0801 | 0.128 | -0.690 |
| 13 | 0.157 | 0.309 | -0.918 |
| 14 | 0.0767 | 0.106 | -0.693 |
| 15 | 0.0321 | 0.226 | 0.393 |
| 16 | 0.0000653 | 0.106 | 0.0173 |
| 17 | 0.0118 | 0.471 | 0.234 |

APPENDIX D
 STATISTICAL SUMMARIES OF MULTIPLE LINEAR REGRESSION ANALYSES
 FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = -0.126 + (0.700 * \log \text{TOC}) - (0.794 * \log (\text{H/A})) + (0.650 * \text{Log TDS+TSS})$$

N = 17

R = 0.932 Rsqr = 0.869 Adj Rsqr = 0.838

Standard Error of Estimate = 0.122

| | Coefficient | Std. Error | t | P | VIF |
|-------------|-------------|------------|--------|--------|-------|
| Constant | -0.126 | 0.536 | -0.235 | 0.818 | |
| log TOC | 0.700 | 0.149 | 4.692 | <0.001 | 1.304 |
| log (H/A) | -0.794 | 0.226 | -3.517 | 0.004 | 1.332 |
| Log TDS+TSS | 0.650 | 0.232 | 2.796 | 0.015 | 1.071 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|----|-------|--------|--------|--------|
| Regression | 3 | 1.287 | 0.429 | 28.629 | <0.001 |
| Residual | 13 | 0.195 | 0.0150 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SSIncr | SSMarg |
|-------------|--------|--------|
| log TOC | 0.923 | 0.330 |
| log (H/A) | 0.247 | 0.185 |
| Log TDS+TSS | 0.117 | 0.117 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|-------------|--------|
| log TOC | <0.001 |
| log (H/A) | 0.004 |
| Log TDS+TSS | 0.015 |

All independent variables appear to contribute to predicting Log LC50 (P < 0.05).

Normality Test (Shapiro-Wilk) Passed (P = 0.444)

Constant Variance Test: Passed (P = 0.271)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFFITS |
|-----|--------------|----------|---------|
| 1 | 0.0389 | 0.202 | -0.388 |
| 2 | 0.00455 | 0.0819 | 0.131 |
| 3 | 0.0459 | 0.273 | 0.419 |
| 4 | 0.0224 | 0.0840 | 0.299 |
| 5 | 0.345 | 0.239 | 1.387 |
| 6 | 0.0854 | 0.134 | 0.616 |
| 7 | 0.120 | 0.417 | -0.683 |
| 8 | 0.672 | 0.595 | 1.699 |
| 9 | 0.00617 | 0.181 | -0.152 |
| 10 | 0.224 | 0.429 | -0.955 |
| 11 | 0.0350 | 0.385 | 0.363 |
| 12 | 0.0651 | 0.0946 | -0.545 |
| 13 | 0.0285 | 0.150 | -0.333 |
| 14 | 0.0256 | 0.141 | -0.315 |
| 15 | 0.00121 | 0.180 | -0.0670 |
| 16 | 0.00338 | 0.124 | -0.112 |
| 17 | 0.0466 | 0.291 | -0.422 |

APPENDIX D
STATISTICAL SUMMARIES OF MULTIPLE LINEAR REGRESSION ANALYSES
FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = -0.0365 + (0.630 * \log \text{DOC}) - (0.447 * \log (\text{H/A})) + (0.640 * \text{Log TDS+TSS})$$

N = 17

R = 0.931 Rsqr = 0.867 Adj Rsqr = 0.837

Standard Error of Estimate = 0.123

| | Coefficient | Std. Error | t | P | VIF |
|-------------|--------------------|-------------------|----------|----------|------------|
| Constant | -0.0365 | 0.536 | -0.0682 | 0.947 | |
| log DOC | 0.630 | 0.135 | 4.658 | <0.001 | 1.868 |
| log (H/A) | -0.447 | 0.269 | -1.662 | 0.120 | 1.872 |
| Log TDS+TSS | 0.640 | 0.234 | 2.737 | 0.017 | 1.073 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|-----------|-----------|-----------|----------|----------|
| Regression | 3 | 1.286 | 0.429 | 28.332 | <0.001 |
| Residual | 13 | 0.197 | 0.0151 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SS Incr | SS Marg |
|---------------|----------------|----------------|
| log DOC | 1.113 | 0.328 |
| log (H/A) | 0.0595 | 0.0418 |
| Log TDS+TSS | 0.113 | 0.113 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|-------------|----------|
| log DOC | <0.001 |
| log (H/A) | 0.120 |
| Log TDS+TSS | 0.017 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified). The following appear to account for the ability to predict Log LC50 (P < 0.05): log DOC, Log TDS+TSS

Normality Test (Shapiro-Wilk) Passed (P = 0.366)

Constant Variance Test: Passed (P = 0.307)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFBETIS |
|------------|---------------------|-----------------|----------------|
| 1 | 0.000579 | 0.103 | 0.0463 |
| 2 | 0.0000751 | 0.0958 | 0.0167 |
| 3 | 0.0823 | 0.283 | 0.570 |
| 4 | 0.00422 | 0.0815 | 0.126 |
| 5 | 0.345 | 0.233 | 1.398 |
| 6 | 0.0120 | 0.176 | 0.212 |
| 7 | 0.0466 | 0.497 | -0.418 |
| 8 | 0.409 | 0.574 | 1.291 |
| 9 | 0.00448 | 0.178 | -0.129 |
| 10 | 0.0492 | 0.483 | -0.430 |
| 11 | 0.0261 | 0.381 | 0.313 |
| 12 | 0.0642 | 0.0945 | -0.541 |
| 13 | 0.117 | 0.197 | -0.712 |
| 14 | 0.102 | 0.0983 | -0.726 |
| 15 | 0.0268 | 0.148 | 0.322 |
| 16 | 0.000153 | 0.101 | 0.0238 |
| 17 | 0.000276 | 0.275 | -0.0320 |

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 FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = 1.330 + (0.697 * \log \text{ TOC}) - (0.907 * \log (\text{H/A})) + (0.176 * \text{Log TSS}) - (0.0110 * \text{pH})$$

N = 17

R = 0.903 Rsqr = 0.815 Adj Rsqr = 0.753

Standard Error of Estimate = 0.151

| | Coefficient | Std. Error | t | P | VIF |
|-----------|--------------------|-------------------|----------|----------|------------|
| Constant | 1.330 | 0.741 | 1.794 | 0.098 | |
| log TOC | 0.697 | 0.199 | 3.500 | 0.004 | 1.524 |
| log (H/A) | -0.907 | 0.275 | -3.299 | 0.006 | 1.295 |
| Log TSS | 0.176 | 0.139 | 1.267 | 0.229 | 1.022 |
| pH | -0.0110 | 0.0804 | -0.137 | 0.893 | 1.191 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|-----------|-----------|-----------|----------|----------|
| Regression | 4 | 1.208 | 0.302 | 13.189 | <0.001 |
| Residual | 12 | 0.275 | 0.0229 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SSIncr | SSMarg |
|---------------|---------------|---------------|
| log TOC | 0.923 | 0.280 |
| log (H/A) | 0.247 | 0.249 |
| Log TSS | 0.0369 | 0.0368 |
| pH | 0.000428 | 0.000428 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|-----------|----------|
| log TOC | 0.004 |
| log (H/A) | 0.006 |
| Log TSS | 0.229 |
| pH | 0.893 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified).
 The following appear to account for the ability to predict Log LC50 (P < 0.05): log TOC, log (H/A)

Normality Test (Shapiro-Wilk) Passed (P = 0.131)

Constant Variance Test: Passed (P = 0.182)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFBETTS |
|------------|---------------------|-----------------|----------------|
| 1 | 0.000782 | 0.286 | -0.0599 |
| 2 | 0.0469 | 0.209 | 0.482 |
| 3 | 0.00715 | 0.273 | 0.182 |
| 4 | 0.00745 | 0.0884 | 0.188 |
| 5 | 0.116 | 0.245 | 0.790 |
| 6 | 0.0805 | 0.189 | 0.657 |
| 7 | 0.130 | 0.467 | -0.797 |
| 8 | 0.246 | 0.204 | 1.371 |
| 9 | 0.00226 | 0.275 | -0.102 |
| 10 | 0.218 | 0.714 | -1.019 |
| 11 | 0.0222 | 0.213 | -0.325 |
| 12 | 0.0209 | 0.164 | -0.317 |
| 13 | 0.128 | 0.319 | -0.812 |
| 14 | 0.114 | 0.263 | -0.778 |
| 15 | 0.0251 | 0.377 | -0.342 |
| 16 | 0.00409 | 0.139 | -0.138 |
| 17 | 0.409 | 0.576 | -1.465 |

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STATISTICAL SUMMARIES OF MULTIPLE LINEAR REGRESSION ANALYSES
FREEMPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = 0.906 + (0.689 * \text{log DOC}) - (0.509 * \text{log (H/A)}) + (0.137 * \text{Log TSS}) + (0.0460 * \text{pH})$$

N = 17

R = 0.900 Rsqr = 0.811 Adj Rsqr = 0.748

Standard Error of Estimate = 0.153

| | Coefficient | Std. Error | t | P | VIF |
|-----------|-------------|------------|--------|-------|-------|
| Constant | 0.906 | 0.828 | 1.094 | 0.296 | |
| log DOC | 0.689 | 0.201 | 3.427 | 0.005 | 2.672 |
| log (H/A) | -0.509 | 0.348 | -1.465 | 0.169 | 2.027 |
| Log TSS | 0.137 | 0.142 | 0.970 | 0.351 | 1.047 |
| pH | 0.0460 | 0.0889 | 0.518 | 0.614 | 1.427 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|----|-------|--------|--------|--------|
| Regression | 4 | 1.202 | 0.300 | 12.852 | <0.001 |
| Residual | 12 | 0.281 | 0.0234 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SS Incr | SS Marg |
|-----------|---------|---------|
| log DOC | 1.113 | 0.275 |
| log (H/A) | 0.0595 | 0.0502 |
| Log TSS | 0.0232 | 0.0220 |
| pH | 0.00627 | 0.00627 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|-----------|-------|
| log DOC | 0.005 |
| log (H/A) | 0.169 |
| Log TSS | 0.351 |
| pH | 0.614 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified).
The following appear to account for the ability to predict Log LC50 (P < 0.05): log DOC

Normality Test (Shapiro-Wilk) Passed (P = 0.962)

Constant Variance Test: Passed (P = 0.694)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFBETTS |
|-----|--------------|----------|---------|
| 1 | 0.0115 | 0.179 | 0.232 |
| 2 | 0.0269 | 0.209 | 0.359 |
| 3 | 0.0141 | 0.280 | 0.256 |
| 4 | 0.000422 | 0.0870 | 0.0440 |
| 5 | 0.119 | 0.239 | 0.803 |
| 6 | 0.0150 | 0.212 | 0.265 |
| 7 | 0.0406 | 0.628 | -0.433 |
| 8 | 0.191 | 0.188 | 1.155 |
| 9 | 0.00412 | 0.282 | -0.138 |
| 10 | 0.168 | 0.713 | -0.889 |
| 11 | 0.0372 | 0.201 | -0.426 |
| 12 | 0.0405 | 0.189 | -0.447 |
| 13 | 0.187 | 0.322 | -1.014 |
| 14 | 0.181 | 0.181 | -1.123 |
| 15 | 0.00755 | 0.319 | 0.187 |
| 16 | 0.0000720 | 0.115 | -0.0182 |
| 17 | 0.000421 | 0.657 | 0.0439 |

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 STATISTICAL SUMMARIES OF MULTIPLE LINEAR REGRESSION ANALYSES
 FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = 1.232 + (0.707 * \log \text{TOC}) - (0.905 * \log (\text{H/A})) + (0.176 * \text{Log TSS})$$

N = 17

R = 0.902 Rsqr = 0.814 Adj Rsqr = 0.772

Standard Error of Estimate = 0.145

| | Coefficient | Std. Error | t | P | VIF |
|-----------|-------------|------------|--------|--------|-------|
| Constant | 1.232 | 0.186 | 6.631 | <0.001 | |
| log TOC | 0.707 | 0.178 | 3.975 | 0.002 | 1.315 |
| log (H/A) | -0.905 | 0.264 | -3.428 | 0.004 | 1.293 |
| Log TSS | 0.176 | 0.133 | 1.321 | 0.209 | 1.021 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|----|-------|--------|--------|--------|
| Regression | 3 | 1.207 | 0.402 | 19.014 | <0.001 |
| Residual | 13 | 0.275 | 0.0212 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SSIncr | SSMarg |
|-----------|--------|--------|
| log TOC | 0.923 | 0.334 |
| log (H/A) | 0.247 | 0.249 |
| Log TSS | 0.0369 | 0.0369 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|-----------|-------|
| log TOC | 0.002 |
| log (H/A) | 0.004 |
| Log TSS | 0.209 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified). The following appear to account for the ability to predict Log LC50 (P < 0.05): log TOC, log (H/A)

Normality Test (Shapiro-Wilk) Passed (P = 0.077)

Constant Variance Test: Passed (P = 0.126)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFFITS |
|-----|--------------|----------|---------|
| 1 | 0.00139 | 0.271 | -0.0717 |
| 2 | 0.0318 | 0.118 | 0.356 |
| 3 | 0.00955 | 0.273 | 0.189 |
| 4 | 0.0100 | 0.0883 | 0.195 |
| 5 | 0.143 | 0.228 | 0.788 |
| 6 | 0.106 | 0.183 | 0.676 |
| 7 | 0.125 | 0.424 | -0.698 |
| 8 | 0.329 | 0.203 | 1.419 |
| 9 | 0.00325 | 0.229 | -0.110 |
| 10 | 0.0735 | 0.453 | -0.528 |
| 11 | 0.0238 | 0.170 | -0.302 |
| 12 | 0.0250 | 0.144 | -0.311 |
| 13 | 0.0397 | 0.135 | -0.399 |
| 14 | 0.123 | 0.234 | -0.718 |
| 15 | 0.0216 | 0.263 | -0.285 |
| 16 | 0.00556 | 0.133 | -0.144 |
| 17 | 0.230 | 0.452 | -0.963 |

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 STATISTICAL SUMMARIES OF MULTIPLE LINEAR REGRESSION ANALYSES
 FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = 1.325 + (0.634 * \log \text{DOC}) - (0.560 * \log (\text{H/A})) + (0.141 * \text{Log TSS})$$

N = 17

R = 0.898 Rsqr = 0.807 Adj Rsqr = 0.762

Standard Error of Estimate = 0.149

| | Coefficient | Std. Error | t | P | VIF |
|-----------|-------------|------------|--------|--------|-------|
| Constant | 1.325 | 0.172 | 7.715 | <0.001 | |
| log DOC | 0.634 | 0.166 | 3.825 | 0.002 | 1.925 |
| log (H/A) | -0.560 | 0.324 | -1.730 | 0.107 | 1.864 |
| Log TSS | 0.141 | 0.138 | 1.025 | 0.324 | 1.045 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|----|-------|--------|--------|--------|
| Regression | 3 | 1.195 | 0.398 | 18.063 | <0.001 |
| Residual | 13 | 0.287 | 0.0221 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SS Incr | SS Marg |
|-----------|---------|---------|
| log DOC | 1.113 | 0.323 |
| log (H/A) | 0.0595 | 0.0660 |
| Log TSS | 0.0232 | 0.0232 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|-----------|-------|
| log DOC | 0.002 |
| log (H/A) | 0.107 |
| Log TSS | 0.324 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified).
 The following appear to account for the ability to predict Log LC50 (P < 0.05): log DOC

Normality Test (Shapiro-Wilk) Passed (P = 0.838)

Constant Variance Test: Passed (P = 0.981)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFBETIS |
|-----|--------------|----------|----------|
| 1 | 0.0174 | 0.166 | 0.257 |
| 2 | 0.0134 | 0.145 | 0.225 |
| 3 | 0.0174 | 0.279 | 0.255 |
| 4 | 0.000808 | 0.0827 | 0.0547 |
| 5 | 0.141 | 0.233 | 0.780 |
| 6 | 0.0211 | 0.211 | 0.282 |
| 7 | 0.0823 | 0.495 | -0.559 |
| 8 | 0.250 | 0.188 | 1.178 |
| 9 | 0.000425 | 0.221 | -0.0396 |
| 10 | 0.00256 | 0.497 | -0.0973 |
| 11 | 0.0273 | 0.163 | -0.325 |
| 12 | 0.0297 | 0.150 | -0.340 |
| 13 | 0.140 | 0.192 | -0.796 |
| 14 | 0.235 | 0.172 | -1.155 |
| 15 | 0.0161 | 0.247 | 0.245 |
| 16 | 0.0000892 | 0.110 | -0.00574 |
| 17 | 0.0184 | 0.448 | -0.261 |

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 FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = 0.705 + (0.730 * \text{log TOC}) - (0.549 * \text{log Hardness}) + (0.837 * \text{log Alkalinity}) + (0.102 * \text{Log TSS})$$

N = 17

R = 0.919 Rsq = 0.844 Adj Rsq = 0.792

Standard Error of Estimate = 0.139

| | Coefficient | Std. Error | t | P | VIF |
|----------------|-------------|------------|--------|-------|-------|
| Constant | 0.705 | 0.390 | 1.807 | 0.096 | |
| log TOC | 0.730 | 0.170 | 4.286 | 0.001 | 1.325 |
| log Hardness | -0.549 | 0.344 | -1.596 | 0.136 | 3.899 |
| log Alkalinity | 0.837 | 0.256 | 3.271 | 0.007 | 4.052 |
| Log TSS | 0.102 | 0.136 | 0.752 | 0.467 | 1.171 |

Warning: Multicollinearity is present among the independent variables. The variables with the largest values of VIF are causing the problem. Consider getting more data or eliminating one or more variables from the equation. The likely candidates for elimination are: log Alkalinity

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|----|-------|--------|--------|--------|
| Regression | 4 | 1.251 | 0.313 | 16.270 | <0.001 |
| Residual | 12 | 0.231 | 0.0192 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SS Incr | SS Marg |
|----------------|---------|---------|
| log TOC | 0.923 | 0.353 |
| log Hardness | 0.117 | 0.0490 |
| log Alkalinity | 0.200 | 0.206 |
| Log TSS | 0.0109 | 0.0109 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|----------------|-------|
| log TOC | 0.001 |
| log Hardness | 0.136 |
| log Alkalinity | 0.007 |
| Log TSS | 0.467 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified). The following appear to account for the ability to predict Log LC50 (P < 0.05): log TOC, log Alkalinity

Normality Test (Shapiro-Wilk) Failed (P = 0.008)

Constant Variance Test: Passed (P = 0.222)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFBETTS |
|-----|--------------|----------|---------|
| 1 | 0.0181 | 0.303 | -0.291 |
| 2 | 0.0211 | 0.134 | 0.320 |
| 3 | 0.0564 | 0.324 | 0.521 |
| 4 | 0.131 | 0.244 | 0.852 |
| 5 | 0.183 | 0.243 | 1.049 |
| 6 | 0.0804 | 0.189 | 0.656 |
| 7 | 0.146 | 0.428 | -0.853 |
| 8 | 0.884 | 0.565 | 2.377 < |
| 9 | 0.0347 | 0.286 | -0.406 |
| 10 | 0.137 | 0.467 | -0.819 |
| 11 | 0.00696 | 0.220 | -0.180 |

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| | | | |
|----|---------|-------|--------|
| 12 | 0.0743 | 0.197 | -0.624 |
| 13 | 0.0242 | 0.169 | -0.342 |
| 14 | 0.0692 | 0.347 | -0.579 |
| 15 | 0.00524 | 0.285 | -0.155 |
| 16 | 0.00906 | 0.139 | -0.206 |
| 17 | 0.154 | 0.458 | -0.872 |

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 FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = 0.621 + (0.690 * \log \text{DOC}) - (0.0456 * \log \text{Hardness}) + (0.417 * \log \text{Alkalinity}) + (0.0393 * \text{Log TSS})$$

N = 17

R = 0.925 Rsqr = 0.855 Adj Rsqr = 0.807

Standard Error of Estimate = 0.134

| | Coefficient | Std. Error | t | P | VIF |
|----------------|-------------|------------|--------|--------|-------|
| Constant | 0.621 | 0.383 | 1.621 | 0.131 | |
| log DOC | 0.690 | 0.152 | 4.545 | <0.001 | 1.992 |
| log Hardness | -0.0456 | 0.388 | -0.117 | 0.908 | 5.334 |
| log Alkalinity | 0.417 | 0.300 | 1.390 | 0.190 | 5.998 |
| Log TSS | 0.0393 | 0.134 | 0.294 | 0.774 | 1.220 |

Warning: Multicollinearity is present among the independent variables. The variables with the largest values of VIF are causing the problem. Consider getting more data or eliminating one or more variables from the equation. The likely candidates for elimination are: log Hardness, log Alkalinity

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|----|-------|--------|--------|--------|
| Regression | 4 | 1.268 | 0.317 | 17.722 | <0.001 |
| Residual | 12 | 0.215 | 0.0179 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SSIncr | SSMarg |
|----------------|---------|----------|
| log DOC | 1.113 | 0.369 |
| log Hardness | 0.120 | 0.000247 |
| log Alkalinity | 0.0331 | 0.0346 |
| Log TSS | 0.00154 | 0.00154 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|----------------|--------|
| log DOC | <0.001 |
| log Hardness | 0.908 |
| log Alkalinity | 0.190 |
| Log TSS | 0.774 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified). The following appear to account for the ability to predict Log LC50 (P < 0.05): log DOC

Normality Test (Shapiro-Wilk) Passed (P = 0.685)

Constant Variance Test: Passed (P = 0.280)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFFITs |
|-----|--------------|----------|--------|
| 1 | 0.00291 | 0.203 | 0.116 |
| 2 | 0.00349 | 0.169 | 0.127 |
| 3 | 0.124 | 0.339 | 0.794 |
| 4 | 0.0757 | 0.233 | 0.622 |
| 5 | 0.189 | 0.241 | 1.074 |
| 6 | 0.00775 | 0.224 | 0.190 |
| 7 | 0.0786 | 0.495 | -0.610 |
| 8 | 0.392 | 0.525 | 1.452 |
| 9 | 0.0382 | 0.285 | -0.427 |

APPENDIX D
STATISTICAL SUMMARIES OF MULTIPLE LINEAR REGRESSION ANALYSES
FREEPORT-MCMORAN CHINO MINES COMPANY
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| | | | |
|----|----------|-------|---------|
| 10 | 0.0262 | 0.504 | -0.348 |
| 11 | 0.00526 | 0.224 | -0.156 |
| 12 | 0.127 | 0.215 | -0.851 |
| 13 | 0.106 | 0.214 | -0.760 |
| 14 | 0.238 | 0.277 | -1.215 |
| 15 | 0.0645 | 0.278 | 0.564 |
| 16 | 0.000989 | 0.117 | -0.0674 |
| 17 | 0.000901 | 0.457 | -0.0643 |

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 FREEPORT-MCMORAN CHINO MINES COMPANY
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Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = 0.993 + (0.698 * \log \text{ TOC}) - (0.530 * \log \text{ Hardness}) + (0.838 * \log \text{ Alkalinity}) + (0.0960 * \text{ Log TSS}) - (0.0365 * \text{ pH})$$

N = 17

R = 0.921 Rsqr = 0.847 Adj Rsqr = 0.778

Standard Error of Estimate = 0.143

| | Coefficient | Std. Error | t | P | VIF |
|----------------|--------------------|-------------------|----------|----------|------------|
| Constant | 0.993 | 0.736 | 1.348 | 0.205 | |
| log TOC | 0.698 | 0.189 | 3.695 | 0.004 | 1.524 |
| log Hardness | -0.530 | 0.358 | -1.481 | 0.167 | 3.949 |
| log Alkalinity | 0.838 | 0.265 | 3.167 | 0.009 | 4.053 |
| Log TSS | 0.0960 | 0.141 | 0.680 | 0.511 | 1.181 |
| pH | -0.0365 | 0.0780 | -0.468 | 0.649 | 1.247 |

Warning: Multicollinearity is present among the independent variables. The variables with the largest values of VIF are causing the problem. Consider getting more data or eliminating one or more variables from the equation. The likely candidates for elimination are: log Alkalinity

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|-----------|-----------|-----------|----------|----------|
| Regression | 5 | 1.256 | 0.251 | 12.212 | <0.001 |
| Residual | 11 | 0.226 | 0.0206 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SS Incr | SS Marg |
|----------------|----------------|----------------|
| log TOC | 0.923 | 0.281 |
| log Hardness | 0.117 | 0.0451 |
| log Alkalinity | 0.200 | 0.206 |
| Log TSS | 0.0109 | 0.00950 |
| pH | 0.00450 | 0.00450 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|----------------|----------|
| log TOC | 0.004 |
| log Hardness | 0.167 |
| log Alkalinity | 0.009 |
| Log TSS | 0.511 |
| pH | |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified). The following appear to account for the ability to predict Log LC50 (P < 0.05): log TOC, log Alkalinity

Normality Test (Shapiro-Wilk) Failed (P = 0.035)

Constant Variance Test: Passed (P = 0.415)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFBETIS |
|------------|---------------------|-----------------|----------------|
| 1 | 0.0117 | 0.311 | -0.254 |
| 2 | 0.0248 | 0.247 | 0.376 |
| 3 | 0.0492 | 0.328 | 0.533 |
| 4 | 0.118 | 0.253 | 0.890 |
| 5 | 0.144 | 0.255 | 1.008 |
| 6 | 0.0621 | 0.199 | 0.626 |
| 7 | 0.200 | 0.478 | -1.114 |
| 8 | 0.676 | 0.575 | 2.252 < |

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| | | | |
|----|----------|-------|---------|
| 9 | 0.0235 | 0.314 | -0.363 |
| 10 | 0.222 | 0.714 | -1.128 |
| 11 | 0.00299 | 0.289 | -0.128 |
| 12 | 0.0569 | 0.206 | -0.593 |
| 13 | 0.0911 | 0.329 | -0.744 |
| 14 | 0.0659 | 0.357 | -0.620 |
| 15 | 0.000235 | 0.428 | -0.0358 |
| 16 | 0.00645 | 0.143 | -0.190 |
| 17 | 0.376 | 0.576 | -1.553 |

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SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = 0.437 + (0.715 * \text{log DOC}) - (0.0328 * \text{log Hardness}) + (0.396 * \text{log Alkalinity}) + (0.0399 * \text{Log TSS}) + (0.0219 * \text{pH})$$

N = 17

R = 0.925 Rsqr = 0.856 Adj Rsqr = 0.791

Standard Error of Estimate = 0.139

| | Coefficient | Std. Error | t | P | VIF |
|----------------|--------------------|-------------------|----------|----------|------------|
| Constant | 0.437 | 0.795 | 0.550 | 0.593 | |
| log DOC | 0.715 | 0.184 | 3.894 | 0.003 | 2.687 |
| log Hardness | -0.0328 | 0.407 | -0.0806 | 0.937 | 5.410 |
| log Alkalinity | 0.396 | 0.322 | 1.229 | 0.245 | 6.381 |
| Log TSS | 0.0399 | 0.139 | 0.286 | 0.780 | 1.220 |
| pH | 0.0219 | 0.0820 | 0.267 | 0.795 | 1.463 |

Warning: Multicollinearity is present among the independent variables. The variables with the largest values of VIF are causing the problem. Consider getting more data or eliminating one or more variables from the equation. The likely candidates for elimination are log Hardness, log Alkalinity

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|-----------|-----------|-----------|----------|----------|
| Regression | 5 | 1.269 | 0.254 | 13.094 | <0.001 |
| Residual | 11 | 0.213 | 0.0194 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SSIncr | SSMarg |
|----------------|---------------|---------------|
| log DOC | 1.113 | 0.294 |
| log Hardness | 0.120 | 0.000126 |
| log Alkalinity | 0.0331 | 0.0293 |
| Log TSS | 0.00154 | 0.00159 |
| pH | 0.00138 | 0.00138 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|----------------|----------|
| log DOC | 0.003 |
| log Hardness | 0.937 |
| log Alkalinity | 0.245 |
| Log TSS | 0.780 |
| pH | 0.795 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified). The following appear to account for the ability to predict Log LC50 (P < 0.05): log DOC

Normality Test (Shapiro-Wilk) Passed (P = 0.774)

Constant Variance Test: Passed (P = 0.326)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFFITs |
|------------|---------------------|-----------------|---------------|
| 1 | 0.00187 | 0.210 | 0.101 |
| 2 | 0.00800 | 0.247 | 0.210 |
| 3 | 0.0944 | 0.340 | 0.757 |
| 4 | 0.0604 | 0.249 | 0.605 |
| 5 | 0.153 | 0.245 | 1.059 |
| 6 | 0.00585 | 0.224 | 0.180 |

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| | | | |
|----|----------|-------|---------|
| 7 | 0.0861 | 0.631 | -0.695 |
| 8 | 0.345 | 0.537 | 1.500 |
| 9 | 0.0464 | 0.329 | -0.517 |
| 10 | 0.192 | 0.713 | -1.047 |
| 11 | 0.00918 | 0.280 | -0.225 |
| 12 | 0.125 | 0.240 | -0.932 |
| 13 | 0.148 | 0.331 | -0.981 |
| 14 | 0.183 | 0.279 | -1.158 |
| 15 | 0.0682 | 0.367 | 0.630 |
| 16 | 0.000918 | 0.120 | -0.0709 |
| 17 | 0.00424 | 0.657 | 0.152 |

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Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = 0.0802 + (0.846 * \text{log TOC}) + (0.471 * \text{log Alkalinity}) + (0.0904 * \text{log TDS})$$

N = 17

R = 0.900 R_{sqr} = 0.810 Adj R_{sqr} = 0.766

Standard Error of Estimate = 0.147

| | Coefficient | Std. Error | t | P | VIF |
|----------------|-------------|------------|-------|--------|-------|
| Constant | 0.0802 | 0.724 | 0.111 | 0.914 | |
| log TOC | 0.846 | 0.166 | 5.107 | <0.001 | 1.114 |
| log Alkalinity | 0.471 | 0.225 | 2.096 | 0.056 | 2.775 |
| log TDS | 0.0904 | 0.437 | 0.207 | 0.839 | 2.605 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|----|-------|--------|--------|--------|
| Regression | 3 | 1.201 | 0.400 | 18.491 | <0.001 |
| Residual | 13 | 0.281 | 0.0216 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SS _{incr} | SS _{Marg} |
|----------------|--------------------|--------------------|
| log TOC | 0.923 | 0.565 |
| log Alkalinity | 0.277 | 0.0951 |
| log TDS | 0.000927 | 0.000927 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|----------------|--------|
| log TOC | <0.001 |
| log Alkalinity | 0.056 |
| log TDS | 0.839 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified).
 The following appear to account for the ability to predict Log LC50 (P < 0.05): log TOC

Normality Test (Shapiro-Wilk) Passed (P = 0.544)

Constant Variance Test: Passed (P = 0.787)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFFITS |
|-----|--------------|----------|----------|
| 1 | 0.0527 | 0.191 | -0.457 |
| 2 | 0.00422 | 0.105 | 0.125 |
| 3 | 0.0725 | 0.140 | 0.557 |
| 4 | 0.269 | 0.267 | 1.134 |
| 5 | 0.149 | 0.222 | 0.811 |
| 6 | 0.0290 | 0.112 | 0.339 |
| 7 | 0.0421 | 0.471 | -0.397 |
| 8 | 0.567 | 0.615 | 1.533 |
| 9 | 0.0330 | 0.234 | -0.355 |
| 10 | 0.340 | 0.355 | -1.244 |
| 11 | 0.0000381 | 0.453 | -0.00375 |
| 12 | 0.0568 | 0.0985 | -0.500 |
| 13 | 0.0180 | 0.149 | -0.262 |
| 14 | 0.000410 | 0.0704 | 0.0389 |
| 15 | 0.00330 | 0.158 | 0.111 |
| 16 | 0.00961 | 0.150 | -0.190 |
| 17 | 0.0790 | 0.209 | -0.567 |

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Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$\text{Log LC50} = 0.134 + (0.718 * \text{log DOC}) + (0.273 * \text{log Alkalinity}) + (0.296 * \text{log TDS(ACZ)})$

N = 17

R = 0.928 Rsq = 0.861 Adj Rsqr = 0.829

Standard Error of Estimate = 0.126

| | Coefficient | Std. Error | t | P | VIF |
|----------------|-------------|------------|-------|--------|-------|
| Constant | 0.134 | 0.618 | 0.217 | 0.832 | |
| log DOC | 0.718 | 0.113 | 6.347 | <0.001 | 1.246 |
| log Alkalinity | 0.273 | 0.202 | 1.353 | 0.199 | 3.046 |
| log TDS (ACZ) | 0.296 | 0.378 | 0.783 | 0.448 | 2.659 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|----|-------|--------|--------|--------|
| Regression | 3 | 1.276 | 0.425 | 26.783 | <0.001 |
| Residual | 13 | 0.206 | 0.0159 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SSIncr | SSMarg |
|----------------|---------|---------|
| log DOC | 1.113 | 0.640 |
| log Alkalinity | 0.153 | 0.0291 |
| log TDS (ACZ) | 0.00973 | 0.00973 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|----------------|--------|
| log DOC | <0.001 |
| log Alkalinity | 0.199 |
| log TDS (ACZ) | 0.448 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified).
 The following appear to account for the ability to predict Log LC50 (P < 0.05): log DOC

Normality Test (Shapiro-Wilk) Passed (P = 0.595)

Constant Variance Test: Passed (P = 0.331)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFBETTS |
|-----|--------------|----------|---------|
| 1 | 0.0000151 | 0.0987 | 0.00746 |
| 2 | 0.0000102 | 0.113 | 0.00615 |
| 3 | 0.0637 | 0.144 | 0.516 |
| 4 | 0.102 | 0.286 | 0.638 |
| 5 | 0.201 | 0.198 | 0.995 |
| 6 | 0.00163 | 0.116 | 0.0777 |
| 7 | 0.00928 | 0.475 | -0.185 |
| 8 | 0.441 | 0.583 | 1.343 |
| 9 | 0.0262 | 0.225 | -0.315 |
| 10 | 0.0826 | 0.471 | -0.560 |
| 11 | 0.00606 | 0.456 | 0.150 |
| 12 | 0.0738 | 0.0961 | -0.589 |
| 13 | 0.118 | 0.186 | -0.718 |
| 14 | 0.0548 | 0.0856 | -0.497 |
| 15 | 0.0327 | 0.110 | 0.362 |
| 16 | 0.000267 | 0.127 | -0.0314 |
| 17 | 0.00169 | 0.230 | -0.0790 |

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Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = 0.220 + (0.843 * \text{logTOC}) + (0.507 * \text{log Alkalinity})$$

N = 17

R = 0.900 Rsqr = 0.810 Adj Rsqr = 0.782

Standard Error of Estimate = 0.142

| | Coefficient | Std. Error | t | P | VIF |
|----------------|-------------|------------|-------|--------|-------|
| Constant | 0.220 | 0.248 | 0.888 | 0.389 | |
| logTOC | 0.843 | 0.159 | 5.292 | <0.001 | 1.105 |
| log Alkalinity | 0.507 | 0.137 | 3.704 | 0.002 | 1.105 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|----|-------|--------|--------|--------|
| Regression | 2 | 1.200 | 0.600 | 29.749 | <0.001 |
| Residual | 14 | 0.282 | 0.0202 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SSIncr | SSMarg |
|----------------|--------|--------|
| logTOC | 0.923 | 0.565 |
| log Alkalinity | 0.277 | 0.277 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|----------------|--------|
| logTOC | <0.001 |
| log Alkalinity | 0.002 |

All independent variables appear to contribute to predicting Log LC50 (P < 0.05).

Normality Test (Shapiro-Wilk) Passed (P = 0.503)

Constant Variance Test: Passed (P = 0.802)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFBETIS |
|-----|--------------|----------|---------|
| 1 | 0.0613 | 0.173 | -0.427 |
| 2 | 0.00396 | 0.0604 | 0.106 |
| 3 | 0.0365 | 0.0642 | 0.339 |
| 4 | 0.216 | 0.174 | 0.878 |
| 5 | 0.178 | 0.203 | 0.765 |
| 6 | 0.0236 | 0.0643 | 0.267 |
| 7 | 0.0365 | 0.306 | -0.322 |
| 8 | 0.506 | 0.515 | 1.253 |
| 9 | 0.0481 | 0.230 | -0.372 |
| 10 | 0.348 | 0.311 | -1.077 |
| 11 | 0.00120 | 0.182 | -0.0578 |
| 12 | 0.0780 | 0.0963 | -0.508 |
| 13 | 0.0242 | 0.133 | -0.264 |
| 14 | 0.000506 | 0.0688 | 0.0376 |
| 15 | 0.00441 | 0.156 | 0.111 |
| 16 | 0.0134 | 0.135 | -0.195 |
| 17 | 0.0500 | 0.127 | -0.388 |

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Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = 0.588 + (0.703 * \text{log DOC}) + (0.395 * \text{log Alkalinity})$$

N = 17

R = 0.924 Rsqr = 0.854 Adj Rsqr = 0.833

Standard Error of Estimate = 0.124

| | Coefficient | Std. Error | t | P | VIF |
|----------------|-------------|------------|-------|--------|-------|
| Constant | 0.588 | 0.209 | 2.811 | 0.014 | |
| log DOC | 0.703 | 0.110 | 6.393 | <0.001 | 1.212 |
| log Alkalinity | 0.395 | 0.125 | 3.152 | 0.007 | 1.212 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|----|-------|--------|--------|--------|
| Regression | 2 | 1.266 | 0.633 | 41.003 | <0.001 |
| Residual | 14 | 0.216 | 0.0154 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SS In cr | SS Marg |
|----------------|----------|---------|
| log DOC | 1.113 | 0.631 |
| log Alkalinity | 0.153 | 0.153 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|----------------|--------|
| log DOC | <0.001 |
| log Alkalinity | 0.007 |

All independent variables appear to contribute to predicting Log LC50 (P < 0.05).

Normality Test (Shapiro-Wilk) Passed (P = 0.467)

Constant Variance Test: Passed (P = 0.321)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFBETIS |
|-----|--------------|----------|---------|
| 1 | 0.000511 | 0.0818 | 0.0378 |
| 2 | 0.000911 | 0.0638 | 0.0504 |
| 3 | 0.0260 | 0.0750 | 0.279 |
| 4 | 0.113 | 0.181 | 0.595 |
| 5 | 0.222 | 0.185 | 0.883 |
| 6 | 0.00365 | 0.0607 | 0.101 |
| 7 | 0.0446 | 0.278 | -0.357 |
| 8 | 0.617 | 0.498 | 1.409 |
| 9 | 0.0412 | 0.221 | -0.344 |
| 10 | 0.0510 | 0.446 | -0.379 |
| 11 | 0.00721 | 0.168 | -0.142 |
| 12 | 0.0922 | 0.0931 | -0.564 |
| 13 | 0.168 | 0.177 | -0.749 |
| 14 | 0.0754 | 0.0856 | -0.504 |
| 15 | 0.0418 | 0.109 | 0.355 |
| 16 | 0.00150 | 0.112 | -0.0647 |
| 17 | 0.000386 | 0.163 | 0.0328 |

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Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = 0.646 + (0.793 * \log \text{ TOC}) + (0.523 * \log \text{ Alkalinity}) - (0.0511 * \text{ pH})$$

N = 17

R = 0.903 Rsqr = 0.816 Adj Rsqr = 0.773

Standard Error of Estimate = 0.145

| | Coefficient | Std. Error | t | P | VIF |
|----------------|-------------|------------|--------|--------|-------|
| Constant | 0.646 | 0.700 | 0.924 | 0.373 | |
| log TOC | 0.793 | 0.180 | 4.403 | <0.001 | 1.354 |
| log Alkalinity | 0.523 | 0.142 | 3.685 | 0.003 | 1.141 |
| pH | -0.0511 | 0.0782 | -0.653 | 0.525 | 1.226 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|----|-------|--------|--------|--------|
| Regression | 3 | 1.209 | 0.403 | 19.163 | <0.001 |
| Residual | 13 | 0.273 | 0.0210 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SSIncr | SSMarg |
|----------------|---------|---------|
| log TOC | 0.923 | 0.408 |
| log Alkalinity | 0.277 | 0.286 |
| pH | 0.00897 | 0.00897 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|----------------|--------|
| log TOC | <0.001 |
| log Alkalinity | 0.003 |
| pH | 0.525 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified). The following appear to account for the ability to predict Log LC50 (P < 0.05): log TOC, log Alkalinity

Normality Test (Shapiro-Wilk) Passed (P = 0.411)

Constant Variance Test: Passed (P = 0.795)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFFITS |
|-----|--------------|----------|---------|
| 1 | 0.0408 | 0.190 | -0.399 |
| 2 | 0.00234 | 0.150 | 0.0931 |
| 3 | 0.0274 | 0.0650 | 0.339 |
| 4 | 0.169 | 0.178 | 0.906 |
| 5 | 0.124 | 0.212 | 0.730 |
| 6 | 0.0173 | 0.0736 | 0.262 |
| 7 | 0.0692 | 0.361 | -0.515 |
| 8 | 0.333 | 0.520 | 1.166 |
| 9 | 0.0280 | 0.255 | -0.326 |
| 10 | 0.751 | 0.605 | -1.807 |
| 11 | 0.000283 | 0.245 | 0.0323 |
| 12 | 0.0604 | 0.113 | -0.511 |
| 13 | 0.109 | 0.286 | -0.664 |
| 14 | 0.0000199 | 0.0969 | 0.00858 |
| 15 | 0.0255 | 0.265 | 0.310 |
| 16 | 0.00836 | 0.138 | -0.177 |
| 17 | 0.142 | 0.245 | -0.780 |

APPENDIX D
 STATISTICAL SUMMARIES OF MULTIPLE LINEAR REGRESSION ANALYSES
 FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

Multiple Linear Regression

Data source: Interim Criteria Adjustment Report ARCADIS2013 (all input variables log transformed)

$$\text{Log LC50} = 0.418 + (0.725 * \text{log DOC}) + (0.384 * \text{log Alkalinity}) + (0.0214 * \text{pH})$$

N = 17

R = 0.925 Rsqr = 0.855 Adj Rsqr = 0.822

Standard Error of Estimate = 0.129

| | Coefficient | Std. Error | t | P | VIF |
|----------------|-------------|------------|-------|--------|-------|
| Constant | 0.418 | 0.632 | 0.662 | 0.520 | |
| log DOC | 0.725 | 0.136 | 5.312 | <0.001 | 1.742 |
| log Alkalinity | 0.384 | 0.136 | 2.824 | 0.014 | 1.329 |
| pH | 0.0214 | 0.0751 | 0.285 | 0.780 | 1.439 |

Analysis of Variance:

| | DF | SS | MS | F | P |
|------------|----|-------|--------|--------|--------|
| Regression | 3 | 1.267 | 0.422 | 25.569 | <0.001 |
| Residual | 13 | 0.215 | 0.0165 | | |
| Total | 16 | 1.482 | 0.0926 | | |

| Column | SS In cr | SS Marg |
|----------------|----------|---------|
| log DOC | 1.113 | 0.466 |
| log Alkalinity | 0.153 | 0.132 |
| pH | 0.00134 | 0.00134 |

The dependent variable Log LC50 can be predicted from a linear combination of the independent variables:

| | P |
|----------------|--------|
| log DOC | <0.001 |
| log Alkalinity | 0.014 |
| pH | 0.780 |

Not all of the independent variables appear necessary (or the multiple linear model may be underspecified).
 The following appear to account for the ability to predict Log LC50 (P < 0.05): log DOC, log Alkalinity

Normality Test (Shapiro-Wilk) Passed (P = 0.674)

Constant Variance Test: Passed (P = 0.454)

Power of performed test with alpha = 0.050: 1.000

Influence Diagnostics:

| Row | Cook's Dist. | Leverage | DFBETIS |
|-----|--------------|----------|---------|
| 1 | 0.000271 | 0.0864 | 0.0316 |
| 2 | 0.00381 | 0.150 | 0.119 |
| 3 | 0.0191 | 0.0817 | 0.275 |
| 4 | 0.0852 | 0.200 | 0.593 |
| 5 | 0.165 | 0.189 | 0.882 |
| 6 | 0.00278 | 0.0622 | 0.102 |
| 7 | 0.0371 | 0.371 | -0.374 |
| 8 | 0.514 | 0.514 | 1.493 |
| 9 | 0.0429 | 0.254 | -0.406 |
| 10 | 0.223 | 0.632 | -0.925 |
| 11 | 0.0137 | 0.239 | -0.226 |
| 12 | 0.0892 | 0.116 | -0.646 |
| 13 | 0.222 | 0.289 | -0.993 |
| 14 | 0.0528 | 0.0861 | -0.485 |
| 15 | 0.0581 | 0.209 | 0.480 |
| 16 | 0.00126 | 0.115 | -0.0683 |
| 17 | 0.0124 | 0.405 | 0.215 |



Appendix E

**Evaluation of STSIU Surface-
Water Chemistry Ranges**

Appendix E

Evaluation of STSIU Surface-Water Chemistry Ranges

Based on available surface-water data, this Appendix presents an evaluation of chemistry ranges measured in STSIU surface waters. The purpose of this evaluation is to assess whether the chemistry range used to develop the WER model sufficiently represents the range of water chemistries in the STSIU study area.

Available surface-water data were collected during the monsoon season during three different years: 2010, 2011, and 2013. The map in Figure E-1 shows locations of samples collected during these sampling efforts. A summary of these data is provided below.

- **2010 Wet Season Survey:** This study was performed in September of 2010 to gain a general understanding of STSIU water chemistry ranges and whether SSC could be developed in the STSIU surface waters. A total of 12 surface-water samples were collected from the current STSIU study area and analyzed for a complete set of water chemistries. Most drainage areas surveyed were dry during this study, which was performed in a relatively dry year. Prior to this sampling effort, surface-water chemistry data available for the Site was generally limited to metals and hardness concentrations (i.e., parameters necessary for evaluating hardness-based compliance). Thus, these surface-water samples provided an initial indication of water chemistry characteristics in STSIU.
- **2011 WER Sampling:** As described in the current report and in ARCADIS (2013a), two rounds of surface-water sampling were conducted three weeks apart during the 2011 monsoon season (in August and September). In total, 18 surface-water samples were collected for WER toxicity tests and analyzed for a complete set of water chemistry and six additional samples were collected and analyzed for water chemistries. Surface water samples used in the WER toxicity tests were collected from ephemeral pools (associated with recent monsoon stormwater runoff) as well as intermittent and perennial pools. Most drainage areas surveyed were dry during this study, which was also performed in a relatively dry year.
- **2013 Wet Season Survey:** An additional round of sampling was performed in August 2013 in accordance with the current work plan methods (ARCADIS 2011) to support this evaluation of chemistry ranges in STSIU surface waters. Relative to conditions from previous wet season sampling efforts (in 2010 and 2011), drainage areas observed during this survey generally contained more water because of strong monsoonal precipitation in 2013. During the initial evaluation of chemistry variability in STSIU surface waters (provided in the draft Criteria Adjustment Interim report), it was noted that 2011 samples captured water chemistry variability. NMED SWQB comments to the Interim Report (received December 2012) observed that although samples represented a spatial and temporal chemistry range, there was no basis to conclude that samples account for all the variability. Statements concerning water chemistry variability and the range of chemistries observed across STSIU surface waters were subsequently modified in the revised Interim Report to better reflect the available data (ARCADIS 2013a). During the development of this WER model report, and based on feedback from NMED SWQB regarding the representativeness of the model to STSIU chemistry ranges, it was determined that additional

surface-water samples could benefit the analysis of model applicability to STSIU surface waters. Therefore, a total of 13 additional samples were collected based on available surface water located throughout the STSIU study area (**Figure E-2**).

Analytical methods used for chemical analyses of these samples were consistent with methods used during the two 2011 WER sampling rounds (refer to **Table 2** in **Appendix A** for a summary of these methods). Photo-documentation of all surface-water pools sampled during field effort is provided as an Attachment to this Appendix (**Attachment E-1**). **Table E-1** lists sample dates, coordinates, dimensions, and field water quality parameters from the 13 surface-water pools sampled during this effort. Strong monsoonal precipitation occurred intermittently during the three days of sampling; as a result, drainage areas generally contained more surface water than observed during previous years as stated previously. However, some drainage areas that were targeted for sample collection were dry (**Figure E-2**) during this effort, including drainage areas that were originally targeted for WER testing in the study work plan (ARCADIS 2011). All surface-water samples were collected from pools, generally found in predominately bedrock sections of drainage channels.

In total, 48 distinct surface-water samples have been collected in the STSIU study area across three different years. A summary of complete water chemistries from these samples is presented in **Table E-2** and **E-3**. These samples represent the extent of available surface-water data that contain the parameters evaluated during SSC development, and specifically the parameters determined to be significant predictors of Site-specific copper toxicity that are used in the proposed WER model (i.e., DOC and alkalinity).

The primary focus of this evaluation is to assess whether the range of water chemistry used to develop the proposed model sufficiently represents the range of water chemistry that occurs in the STSIU study area. To accomplish this, **Figures E3 to E7** compare the measured chemistry range of select parameters from the 17 toxicity tests used to develop the WER model to chemistry ranges across the sampled STSIU subwatersheds. These water chemistry ranges are compared below for each of the selected parameters.

Figure E-3 Dissolved Organic Carbon: DOC is an input parameter in the proposed WER model, and was determined to be the strongest single predictor of Site-specific copper toxicity out of all parameters evaluated (Section 3.2.2). Surface waters used to develop the proposed WER model (N=17) ranged in DOC concentrations from 1.2 mg/L (a Rustler Canyon sample) to 15.7 mg/L (a Subwatershed G sample), representing a total range of more than an order of magnitude. The lowest concentration of DOC from the WER toxicity tests (1.2 mg/L) is also the lowest DOC concentration measured in STSIU surface waters (**Figure E-3**). This indicates the model is calibrated to a sufficiently low DOC range based on expected concentrations. As described in this report, DOC concentrations measured across most of these subwatersheds are very high, ranging up to 19.1 mg/L in a 2013 sample collected just downstream of Ash Spring in Subwatershed B (**Table E-2**).

Figure E-4 Total Organic Carbon: Although not an input parameter in the proposed WER model, TOC was also determined to be a significant predictor of Site-specific copper toxicity in this study.

Similar to DOC, the TOC model range is representative of measured ranges in STSIU surface waters. Of the available surface-water data, TOC in one 2011 sample collected in Rustler Canyon (1.2 mg/L) was below the low-end of the model range (2.7 mg/L TOC). As shown on **Figure E-4**, TOC concentrations in several samples collected from different subwatersheds were greater than the samples used in the WER toxicity tests, ranging up to 20 mg/L (in a 2010 sample collected in Subwatershed D).

Figure E-5 Alkalinity: Alkalinity is an input parameter in the proposed WER model. Surface-water samples used to develop the proposed WER model (N=17) ranged in alkalinity concentrations from 27 mg/L (a Rustler Canyon sample) to 250 mg/L (a Martin Canyon sample). **Figure E-5** shows that this model range covers the majority of alkalinity concentrations measured in STSIU surface waters. As listed in **Table E-2** and shown graphically in **Figure 3**, five samples were used in Site toxicity tests that contained alkalinity concentrations less than or equal to 42 mg/L, indicating the model is well-calibrated to lower alkalinity concentrations. Although lower alkalinity concentrations have been measured in STSIU waters (**Table E-2** and **Figure E-5**), the sensitivity of the model to low alkalinity and margin of safety recommendations for model application together provide the technical basis to apply the model to lower alkalinity concentrations and derive environmentally conservative SSC (**Section 4.2.2.2**).

Figure E-6 Hardness/Alkalinity Ratio: Although not an input parameter in the proposed WER model, the hardness/alkalinity ratio was also determined to be a marginally significant predictor of Site-specific copper toxicity in this study. As shown in **Figure E-6**, the model range captures the majority of measured hardness/alkalinity ratios, and only 3 samples collected in Subwatershed D were greater than the upper model range.

Figure E-7 Total Dissolved Solids: Although not an input parameter in the proposed WER model, TDS was also determined as a marginally significant predictor of Site-specific copper toxicity in this study. **Figure E-7** shows the TDS concentrations used to develop the WER model mostly cover the range measured in STSIU surface waters. The lowest concentration of TDS from the WER toxicity test samples was 90 mg/L (a Rustler Canyon sample), and only a single 2011 sample collected in Rustler Canyon was slightly lower (80 mg/L). One 2013 sample collected in Subwatershed B (downstream of Ash Spring) contained a TDS concentration greater than the upper range of the model.

Conclusions

Overall, this evaluation shows that the ranges of chemistry parameters used to develop the WER model are representative of STSIU surface waters, based on water chemistries observed thus far in STSIU. One of the objectives of the WER study, as described in study work plan (ARCADIS 2011), was to develop a WER model over a representative range of water chemistries based on the unique hydrologic conditions and available aquatic habitats of STSIU. Comparing the range of chemistries used to develop the model with the ranges of available STSIU surface-water data clearly shows that the model was developed over a broad range relative to Site conditions (i.e., limited water). As described previously, applying the model to sample concentrations that are not in the range used to develop the model is not expected to introduce uncertainty towards the under-protectiveness of the SSC.

Specifically, the highest concentrations of DOC and alkalinity used to develop the WER model will be used as the default input values when applying the model to samples that contain concentrations of either or both of these parameters that are greater than the upper model range. This approach will provide conservative SSC, because both parameters protect against copper toxicity as their concentrations increase; and this approach is consistent with guidelines for applying the current hardness-based criteria. Conversely, the recommended approach is to apply the model to sample alkalinity or DOC concentrations that are less than the low-end of the model range to ensure the derived SSC are environmentally conservative. As described in Section 4.2.2.2, although a lower-limit is applied in the current hardness-based approach, less protection against copper toxicity is expected at lower DOC and alkalinity concentrations. Thus, applying the WER model to concentrations less than the low-end of the model range will result in more conservative criteria (i.e., lower SSC values).

**TABLE E-1
SUMMARY OF ALL SURFACE WATER SAMPLING LOCATIONS**

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
SMELTER/TAILINGS SOILS IU SITE-SPECIFIC COPPER TOXICITY MODEL REPORT

| Sample ID | Drainage Description | Sample Date | Longitude | Latitude | Maximum Length (m) | Maximum Width (m) | Maximum Depth (m) | Temperature (°C) | Conductivity (mS/cm) | Dissolved Oxygen (mg/L) | pH |
|-----------------------------------|----------------------|-------------|-------------|-----------|--------------------|-------------------|-------------------|------------------|----------------------|-------------------------|------|
| 2013 Surface Water Samples | | | | | | | | | | | |
| 2013-SW-WER-BD | Drainage C2 | 8/12/2013 | -108.094428 | 32.693932 | 12.19 | 1.82 | -0.30 | 20.89 | 0.114 | 8.2 | 7.72 |
| 2013-SW-WER-5 | Drainage C1-Lower | 8/12/2013 | -108.102190 | 32.696505 | continuous | 6.09 | 0.33 | 24.77 | 0.218 | 7.14 | 6.67 |
| 2013-SW-C-BS | Drainage C1-BC | 8/12/2013 | -108.099237 | 32.717377 | continuous | 1.22 | 0.45 | 26.87 | 0.158 | 7.78 | 7.82 |
| 2013-SW-C-BSD | Drainage C1-BC | 8/12/2013 | -108.099721 | 32.714592 | continuous | 7.62 | 0.61 | 29.93 | 0.147 | 7.81 | 9.12 |
| 2013-SW-WER-6 | Drainage C1-Upper | 8/12/2013 | -108.089900 | 32.722700 | continuous | 2.74 | 0.23 | 24.5 | 0.106 | 2.17 | 6.57 |
| 2013-SW-C-BC | Drainage C1-BC | 8/12/2013 | -108.093780 | 32.730294 | continuous | 3.66 | 0.52 | 26.33 | 0.126 | 6.68 | 6.88 |
| 2013-SW-C2-Lower | Drainage C2 | 8/13/2013 | -108.085180 | 32.708686 | continuous | 1.92 | 0.18 | 20.8 | 0.136 | 7.14 | 7.37 |
| 2013-SW-C2-Upper | Drainage C2 | 8/13/2013 | -108.078281 | 32.715556 | continuous | 2.90 | 0.73 | 22.1 | 0.144 | 6.62 | 7.39 |
| 2013-SW-CDW-1 | Drainage D3 | 8/13/2013 | -108.109901 | 32.704184 | continuous | 3.44 | 0.43 | 26.83 | 0.175 | 6.61 | 5.92 |
| 2013-SW-D2 | Drainage D2 | 8/13/2013 | -108.110698 | 32.727469 | continuous | 1.86 | 0.21 | 25.36 | 0.93 | 6.62 | 6.85 |
| 2013-SW-WER-D1-2 | Drainage D1 | 8/14/2013 | -108.117210 | 32.748760 | 7.32 | 5.18 | 0.17 | 19.25 | 0.15 | 6.71 | 7.04 |
| 2013-SW-WER-7 | Drainage B | 8/14/2013 | -108.068641 | 32.687267 | continuous | 3.11 | 0.55 | 26.65 | 0.221 | 6.62 | 7.42 |
| 2013-SW-B-AS | Drainage B | 8/14/2013 | -108.074127 | 32.709939 | continuous | 1.89 | 0.15 | 25.78 | 0.531 | 5.59 | 7.63 |

Notes:

1. Sample ID nomenclature: Sample year - Sample type - Sample location

m = meters.

°C = degrees celsius.

mS/cm = millisiemens per cm.

mg/L = milligrams per liter.

TABLE E4
SUMMARY OF AVAILABLE STRAW WATER CHEMISTRY - WET CHEMISTRY PARAMETERS

PROJECT: ABBOTT ROAD AND COMPANY
INDUSTRIAL DEVELOPMENT
WELL TREATMENT AND WET CHEMISTRY MONITORING REPORT

| Parameters | Sub-Drainage | Month | Year | Bromate as CaCO ₃ (mg/L) | Dissolved organic carbon (DOC) (mg/L) | Total organic carbon (TOC) (mg/L) | Carbonate as CaCO ₃ (mg/L) | Calcium-Jordan Balance % | Chloride (mg/L) | Hardness as CaCO ₃ (mg/L) | Hydroxide as CaCO ₃ (mg/L) | pH (lab) | pH (field) | pH (DI) | Total dissolved solids (TDS) (mg/L) | Total suspended solids (TSS) (mg/L) | Sulfate (mg/L) | Sum of Anions (mg/L) | Sum of Cations (mg/L) | Total Alkalinity (mg/L) | Dissolved inorganic carbon (mg/L) | Total Inorganic carbon (mg/L) | |
|----------------|--------------|-----------|------|-------------------------------------|---------------------------------------|-----------------------------------|---------------------------------------|--------------------------|-----------------|--------------------------------------|---------------------------------------|----------|------------|---------|-------------------------------------|-------------------------------------|----------------|----------------------|-----------------------|-------------------------|-----------------------------------|-------------------------------|---|
| W19-001-001-01 | Drainage A | September | 2010 | 51 | 0.7 | 0.9 | <2 | — | 2 | 32 | <2 | — | 7.9 | — | 100 | 119 | 38 | — | — | — | — | — | |
| W19-001-001-02 | Drainage A | September | 2010 | 73 | 0 | 0 | <2 | — | 3 | 39 | <2 | — | 7.4 | — | 100 | 111 | 19 | — | — | — | — | — | |
| W19-001-001-03 | Drainage B | September | 2010 | 270 | 0.1 | 0.1 | <2 | — | 0 | 0 | <2 | — | 8.3 | 7.93 | — | — | — | — | — | — | — | — | |
| W19-001-001-04 | Drainage B | September | 2010 | 110 | 0.1 | 0.1 | <2 | — | 0 | 0 | <2 | — | 8.08 | — | — | — | — | — | — | — | — | — | |
| W19-001-001-05 | Drainage B | September | 2010 | 65 | 0.8 | 0.8 | <2 | -2.8 | 2 | 38 | <2 | — | 7.18 | 7.83 | — | — | — | — | — | — | — | — | |
| W19-001-001-06 | Drainage B | September | 2010 | 48 | 0.7 | 0.7 | <2 | — | 0 | 0 | <2 | — | 7.5 | 7.43 | — | — | — | — | — | — | — | — | |
| W19-001-001-07 | Drainage C | September | 2010 | 25 | 0.7 | 0.7 | <2 | — | 0 | 0 | <2 | — | 8.15 | — | — | — | — | — | — | — | — | — | |
| W19-001-001-08 | Drainage C | September | 2010 | 43 | 0.9 | 0.9 | <2 | — | 0 | 0 | <2 | — | 8.08 | — | — | — | — | — | — | — | — | — | |
| W19-001-001-09 | Drainage C | September | 2010 | 24 | 0.8 | 0.8 | <2 | 2.8 | 2 | 32 | <2 | — | 7.8 | 8.08 | 7.84 | — | — | — | — | — | — | — | — |
| W19-001-001-10 | Drainage C | September | 2010 | 26 | 0.8 | 0.8 | <2 | 2.1 | 2 | 22 | <2 | — | 7.8 | 8.07 | — | — | — | — | — | — | — | — | |
| W19-001-001-11 | Drainage C | September | 2010 | 63 | 0.6 | 0.6 | <2 | — | 0 | 0 | <2 | — | 8.07 | — | — | — | — | — | — | — | — | — | |
| W19-001-001-12 | Drainage C | September | 2010 | 41 | 1.2 | 1.2 | <2 | 2.1 | 2 | 24 | <2 | — | 7.8 | 8.12 | 7.87 | — | — | — | — | — | — | — | |
| W19-001-001-13 | Drainage C | September | 2010 | 35 | 1.4 | 1.4 | <2 | 4 | 2 | 30 | <2 | — | 7.8 | 8.04 | 7.76 | — | — | — | — | — | — | — | |
| W19-001-001-14 | Drainage C | September | 2010 | 38 | 1.3 | 1.3 | <2 | 0.9 | 0 | 20 | <2 | — | 7.7 | 8.07 | — | — | — | — | — | — | — | — | |
| W19-001-001-15 | Drainage C | September | 2010 | 47 | 0.8 | 0.8 | <2 | 2.2 | 2 | 22 | <2 | — | 8 | 7.92 | — | — | — | — | — | — | — | — | |
| W19-001-001-16 | Drainage C | September | 2010 | 39 | 0.9 | 0.9 | <2 | 0 | 0 | 0 | <2 | — | 8.3 | 8.12 | — | — | — | — | — | — | — | — | |
| W19-001-001-17 | Drainage C | September | 2010 | 24 | 0.8 | 0.8 | <2 | -10.1 | 0 | 20 | <2 | — | 7.8 | 8.08 | — | — | — | — | — | — | — | — | |
| W19-001-001-18 | Drainage C | September | 2010 | 41 | 0.8 | 0.8 | <2 | — | 0 | 0 | <2 | — | 7.8 | 7.97 | — | — | — | — | — | — | — | — | |
| W19-001-001-19 | Drainage C | September | 2010 | 37 | 1.2 | 1.2 | <2 | 1.8 | 0 | 18 | <2 | — | 7.7 | 7.72 | — | — | — | — | — | — | — | — | |
| W19-001-001-20 | Drainage C | September | 2010 | 32 | 1.3 | 1.3 | <2 | 2.3 | 2 | 22 | <2 | — | 7.8 | 7.97 | — | — | — | — | — | — | — | — | |
| W19-001-001-21 | Drainage C | September | 2010 | 38 | 1.3 | 1.3 | <2 | -0.7 | 0 | 20 | <2 | — | 7.8 | 7.97 | — | — | — | — | — | — | — | — | |
| W19-001-001-22 | Drainage D | September | 2010 | 20 | 0 | 0 | <2 | — | 0 | 0 | <2 | — | 8.1 | — | — | — | — | — | — | — | — | — | |
| W19-001-001-23 | Drainage D | September | 2010 | 21 | 0.9 | 0.9 | <2 | 0.9 | 0 | 18 | <2 | — | 7.8 | 7.81 | 8.09 | — | — | — | — | — | — | — | |
| W19-001-001-24 | Drainage D | September | 2010 | 60 | 0.6 | 0.6 | <2 | 0 | 0 | 0 | <2 | — | 8 | 7.72 | 7.83 | — | — | — | — | — | — | — | |
| W19-001-001-25 | Drainage D | September | 2010 | 28 | 0.8 | 0.8 | <2 | 0 | 0 | 0 | <2 | — | 7.8 | 7.64 | — | — | — | — | — | — | — | — | |
| W19-001-001-26 | Drainage D | September | 2010 | 11 | 0.6 | 0.6 | <2 | — | 0 | 0 | <2 | — | 8.08 | — | — | — | — | — | — | — | — | — | |
| W19-001-001-27 | Drainage D | September | 2010 | 21 | 0.8 | 0.8 | <2 | 1.1 | 0 | 12 | <2 | — | 7.8 | 8.02 | — | — | — | — | — | — | — | — | |
| W19-001-001-28 | Drainage D | September | 2010 | 26 | 1.1 | 1.1 | <2 | -1.5 | 0 | 12 | <2 | — | 7.8 | 7.7 | — | — | — | — | — | — | — | — | |
| W19-001-001-29 | Drainage D | September | 2010 | 16 | 0.8 | 0.8 | <2 | 0.9 | 0 | 18 | <2 | — | 7.8 | 7.81 | — | — | — | — | — | — | — | — | |
| W19-001-001-30 | Drainage D | September | 2010 | 6 | 0.8 | 0.8 | <2 | 0.1 | 0 | 12 | <2 | — | 7.5 | 8.06 | — | — | — | — | — | — | — | — | |
| W19-001-001-31 | Drainage D | September | 2010 | 27 | 0.8 | 0.8 | <2 | 0.4 | 0 | 12 | <2 | — | 8.2 | 8.02 | — | — | — | — | — | — | — | — | |
| W19-001-001-32 | Drainage D | September | 2010 | 10 | 0.7 | 0.7 | <2 | — | 0 | 0 | <2 | — | 8.1 | — | — | — | — | — | — | — | — | — | |
| W19-001-001-33 | Drainage D | September | 2010 | 102 | 0.3 | 0.3 | <2 | 2.7 | 0 | 10 | <2 | — | 8.1 | 7.81 | 7.88 | — | — | — | — | — | — | — | |
| W19-001-001-34 | Drainage D | September | 2010 | 17 | 0.9 | 0.9 | <2 | — | 0 | 0 | <2 | — | 8.1 | — | — | — | — | — | — | — | — | — | |
| W19-001-001-35 | Drainage D | September | 2010 | 10 | 0.8 | 0.8 | <2 | — | 0 | 0 | <2 | — | 8.1 | — | — | — | — | — | — | — | — | — | |
| W19-001-001-36 | Drainage D | September | 2010 | 61 | 0 | 0 | <2 | 2.9 | 0 | 20 | <2 | — | 8.2 | 8.22 | — | — | — | — | — | — | — | — | |
| W19-001-001-37 | Drainage D | September | 2010 | 68 | 0.7 | 0.7 | <2 | 3.6 | 0 | 30 | <2 | — | 8.2 | 7.88 | — | — | — | — | — | — | — | — | |
| W19-001-001-38 | Drainage D | September | 2010 | 14 | 0.8 | 0.8 | <2 | 2.1 | 0 | 18 | <2 | — | 7.8 | 8.53 | 7.87 | — | — | — | — | — | — | — | |
| W19-001-001-39 | Drainage D | September | 2010 | 89 | 1.1 | 1.1 | <2 | 0 | 0 | 0 | <2 | — | 8.2 | 7.84 | 8.18 | — | — | — | — | — | — | — | |
| W19-001-001-40 | Drainage D | September | 2010 | 10 | 0.8 | 0.8 | <2 | — | 0 | 0 | <2 | — | 8.1 | — | — | — | — | — | — | — | — | — | |
| W19-001-001-41 | Drainage D | September | 2010 | 107 | 0.3 | 0.3 | <2 | 1.3 | 0 | 12 | <2 | — | 8.2 | 8.29 | — | — | — | — | — | — | — | — | |
| W19-001-001-42 | Drainage D | September | 2010 | 17 | 0.8 | 0.8 | <2 | 2.3 | 0 | 18 | <2 | — | 8.2 | 8.08 | — | — | — | — | — | — | — | — | |
| W19-001-001-43 | Drainage D | September | 2010 | 80 | 0.3 | 0.3 | <2 | 0 | 0 | 0 | <2 | — | 8.1 | 8.08 | — | — | — | — | — | — | — | — | |
| W19-001-001-44 | Drainage D | September | 2010 | 222 | 0.7 | 0.7 | <2 | 2.1 | 18 | 202 | <2 | — | 8.2 | 7.28 | 8.31 | — | — | — | — | — | — | — | |
| W19-001-001-45 | Drainage D | September | 2010 | 106 | 0.8 | 0.8 | <2 | 0 | 0 | 0 | <2 | — | 8.2 | 7.77 | — | — | — | — | — | — | — | — | |
| W19-001-001-46 | Drainage D | September | 2010 | 38 | 0.1 | 0.1 | <2 | -0.8 | 0 | 12 | <2 | — | 7.8 | — | — | — | — | — | — | — | — | — | |
| W19-001-001-47 | Drainage D | September | 2010 | 27 | 1.2 | 1.2 | <2 | 0 | 0 | 12 | <2 | — | 7.8 | 8.09 | 8.25 | — | — | — | — | — | — | — | |
| W19-001-001-48 | Drainage D | September | 2010 | 21 | 0.5 | 0.5 | <2 | -0.1 | 0 | 12 | <2 | — | 7.8 | 7.28 | 7.4 | — | — | — | — | — | — | — | |
| W19-001-001-49 | Drainage D | September | 2010 | 28 | 0.3 | 0.3 | <2 | 0 | 0 | 0 | <2 | — | 8.6 | 8.47 | 8.57 | — | — | — | — | — | — | — | |
| W19-001-001-50 | Drainage D | September | 2010 | 20 | 0.5 | 0.5 | <2 | 0 | 0 | 0 | <2 | — | 7.8 | 7.24 | — | — | — | — | — | — | — | — | |
| W19-001-001-51 | Drainage D | September | 2010 | 38 | 1.7 | 1.7 | <2 | 0 | 0 | 0 | <2 | — | 7.1 | 6.15 | — | — | — | — | — | — | — | — | |

Notes:
 1. Dissolved inorganic carbon (DIC) is calculated as the sum of carbonate, bicarbonate, and free carbonic acid.
 2. Total inorganic carbon (TIC) is calculated as the sum of DIC and DOC.
 3. Total dissolved solids (TDS) is calculated as the sum of calcium, magnesium, sodium, potassium, chloride, sulfate, and nitrate.
 4. Total suspended solids (TSS) is calculated as the sum of TDS and total suspended matter (TSM).
 5. Total alkalinity is calculated as the sum of carbonate, bicarbonate, and free carbonic acid.
 6. Dissolved inorganic carbon (DIC) is calculated as the sum of carbonate, bicarbonate, and free carbonic acid.
 7. Total inorganic carbon (TIC) is calculated as the sum of DIC and DOC.
 8. Total dissolved solids (TDS) is calculated as the sum of calcium, magnesium, sodium, potassium, chloride, sulfate, and nitrate.
 9. Total suspended solids (TSS) is calculated as the sum of TDS and total suspended matter (TSM).
 10. Total alkalinity is calculated as the sum of carbonate, bicarbonate, and free carbonic acid.



LEGEND:

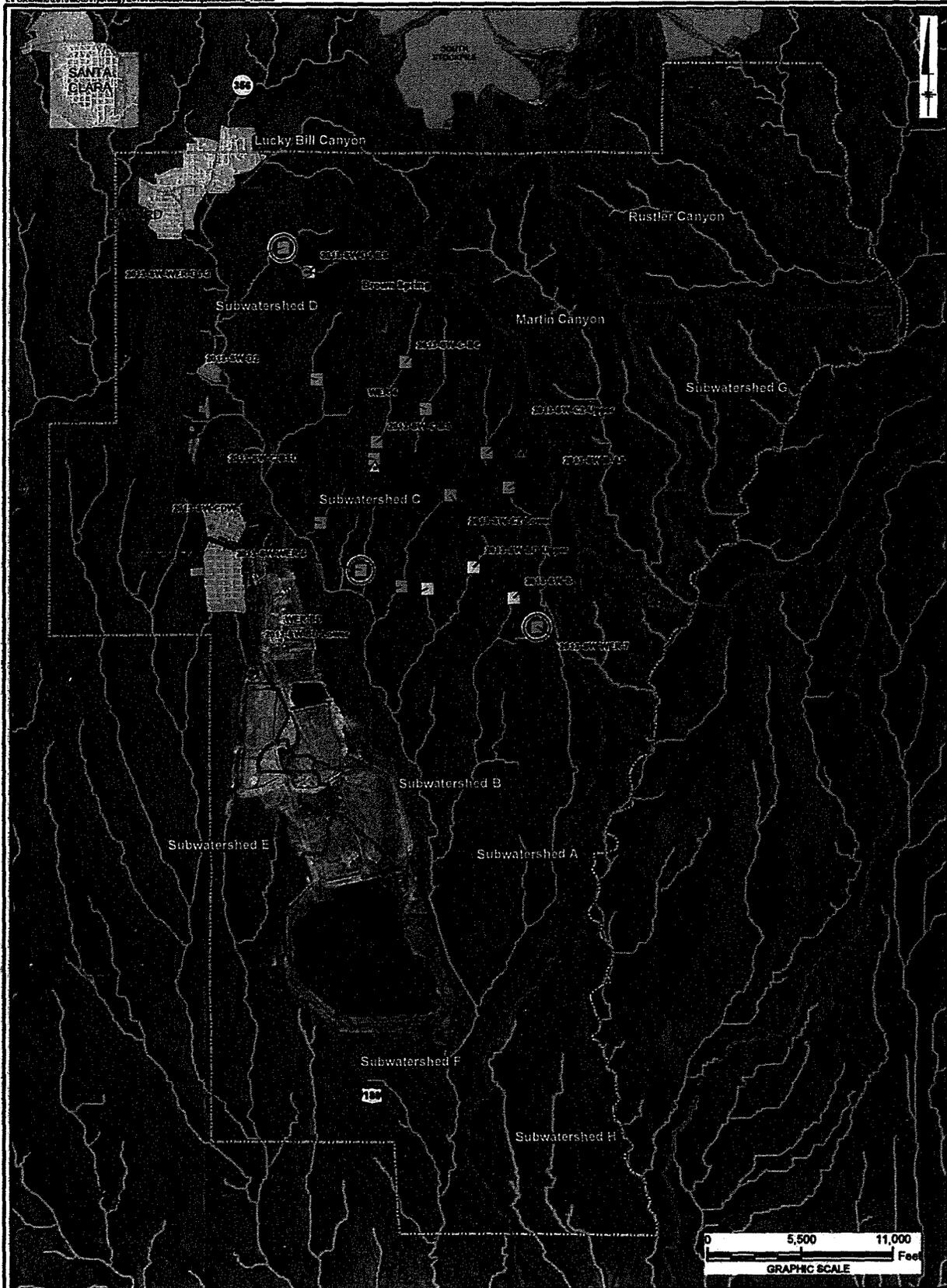
- | | | |
|--|--|---|
| <ul style="list-style-type: none"> — Ephemeral Drainages — Non-Ephemeral Drainages - - - Other Drainages — USFWS Critical Habitat Transect ▭ Lampbright Subwatershed Boundaries ▭ Hanover-Whitewater Subwatershed Boundaries | <ul style="list-style-type: none"> — Highway — Railroad — Town Roads ▲ Ash Spring ▲ Bolton Spring | <ul style="list-style-type: none"> Wet Season Sample Locations ■ 2010 Sample Location ■ 2011 Sample Location ■ 2013 Sample Location ▭ STSIU Study Boundary |
|--|--|---|
- 0 5,500 11,000 Feet
 GRAPHIC SCALE

FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO

**SITE-SPECIFIC COPPER TOXICITY MODEL REPORT
 APPENDIX E**

**STSIU SURFACE WATER SAMPLES
 COLLECTED DURING WET SEASONS IN
 2010, 2011, AND 2013**

ARCADIS | **FIGURE E-1**

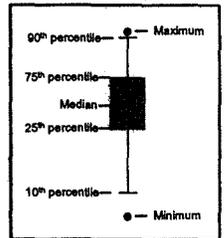
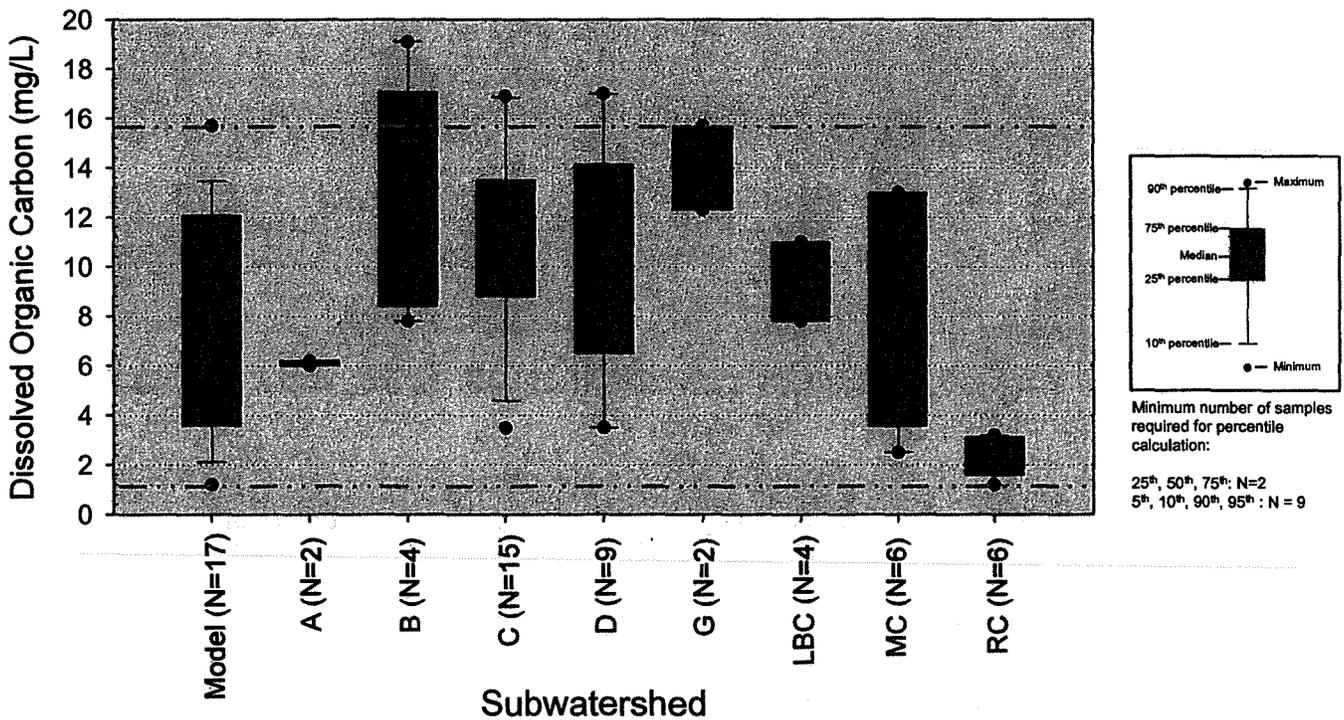


- LEGEND:**
- 2013 Wet Season Surface Water Sample Location
 - 2013 wet season surface water sample location - dry (no sample collected)
 - Confirmatory Water Chemistry Sample from WER Location
 - Ash Spring
 - Bolton Spring
 - STSIU Study Boundary
 - City Areas
 - Lampbright Subwatershed Boundaries
 - Lampbright Subwatersheds within AOC
 - Hanover-Whitewater Subwatershed Boundaries
 - Hanover-Whitewater Subwatersheds within AOC
 - Stockpiles
 - Drainages
 - Highway
 - Railroad
 - Town Roads
 - USFWS Critical Habitat Transect

FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT
 APPENDIX E

**STSIU SURFACE WATER SAMPLES
 COLLECTED DURING THE
 2013 WET SEASON**

ARCADIS | **FIGURE E-2**



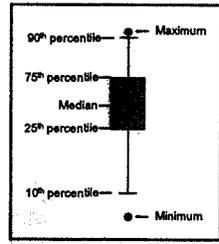
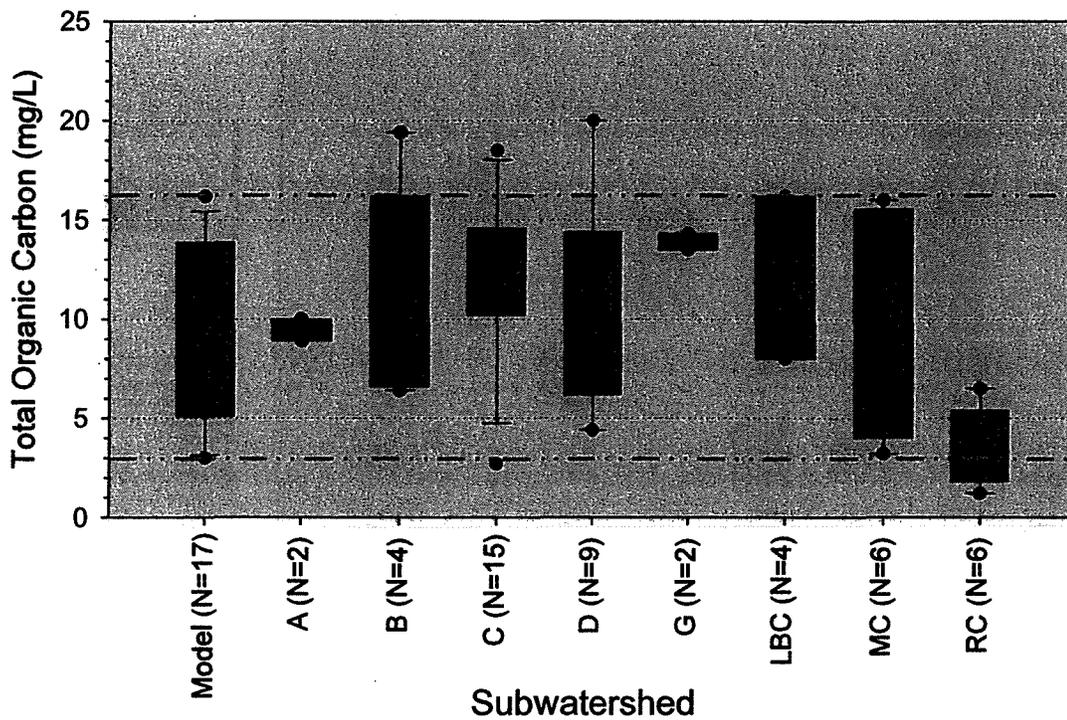
Minimum number of samples required for percentile calculation:

25th, 50th, 75th: N=2
 5th, 10th, 90th, 95th: N=9

Notes:

Model: All samples used in MLR model;
 LBC: Lucky Bill Canyon;
 MC: Martin Canyon;
 RC: Rustler Canyon;
 See Figure E-1 for Subwatershed delineations and sample location distribution;
 Dashed red horizontal lines represent the range of chemistry values from samples used to develop MLR model;
 10th and 90th percentiles not calculated for subwatershed units with less than 9 samples.

| | |
|---|----------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO SITE-SPECIFIC COPPER TOXICITY MODEL REPORT – APPENDIX E | |
| DISSOLVED ORGANIC CARBON RANGE MEASURED ACROSS STSIU SUBWATERSHEDS | |
| | FIGURE E-3 |



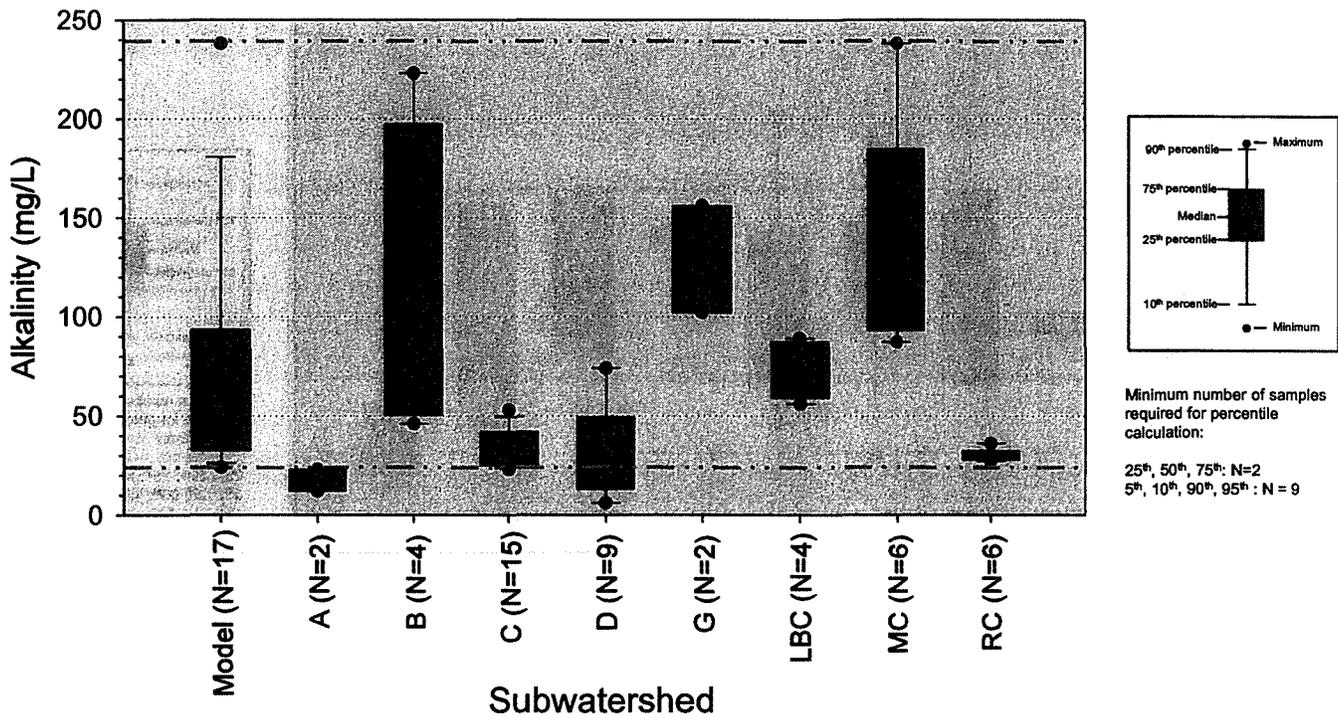
Minimum number of samples required for percentile calculation:

25th, 50th, 75th: N=2
 5th, 10th, 90th, 95th: N=9

Notes:

Model: All samples used in MLR model;
 LBC: Lucky Bill Canyon;
 MC: Martin Canyon;
 RC: Rustler Canyon;
 See Figure E-1 for Subwatershed delineations and sample location distribution;
 Dashed red horizontal lines represent the range of chemistry values from samples used to develop MLR model;
 10th and 90th percentiles not calculated for subwatershed units with less than 9 samples.

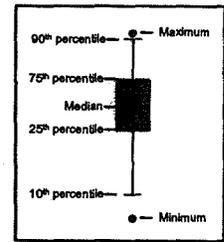
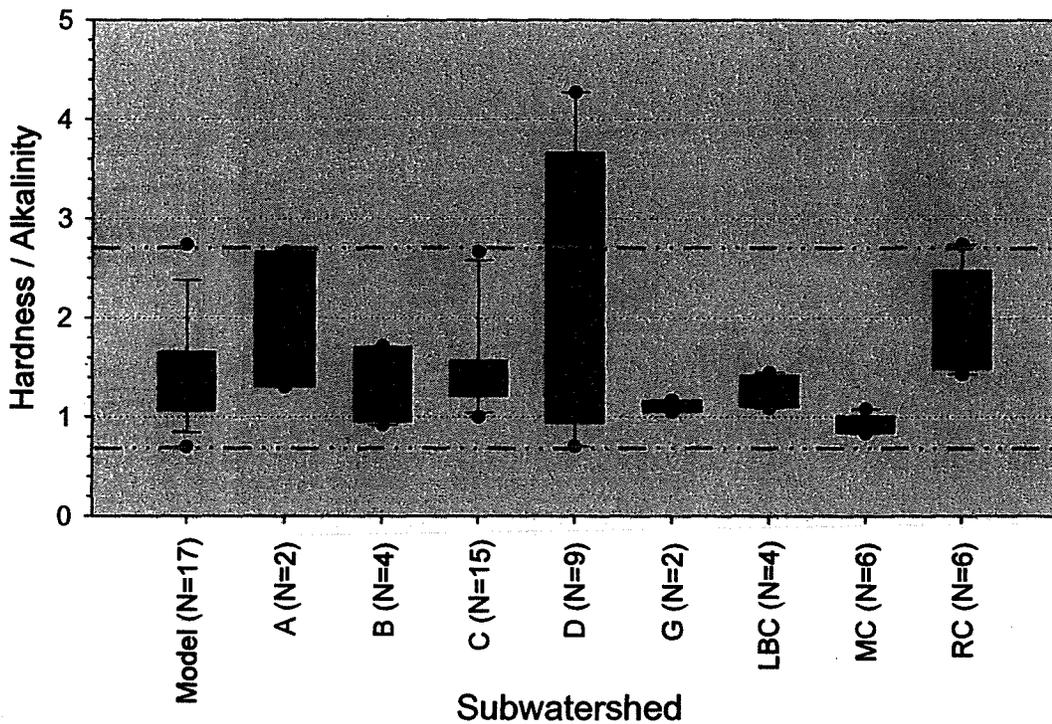
| | |
|--|----------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO SITE-SPECIFIC COPPER TOXICITY MODEL REPORT – APPENDIX E | |
| TOTAL ORGANIC CARBON RANGE MEASURED ACROSS STSIU SUBWATERSHEDS | |
| | FIGURE E-4 |



Notes:

Model: All samples used in MLR model;
 LBC: Lucky Bill Canyon;
 MC: Martin Canyon;
 RC: Rustler Canyon;
 See Figure E-1 for Subwatershed delineations and sample location distribution;
 Dashed red horizontal lines represent the range of chemistry values from samples used to develop MLR model;
 10th and 90th percentiles not calculated for subwatershed units with less than 9 samples.

| | |
|--|-----------------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO SITE-SPECIFIC COPPER TOXICITY MODEL REPORT - APPENDIX E | |
| ALKALINITY RANGE MEASURED ACROSS STSIU SUBWATERSHEDS | |
| | FIGURE E-5 |



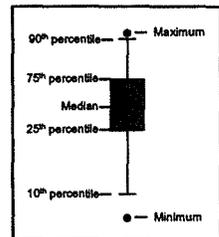
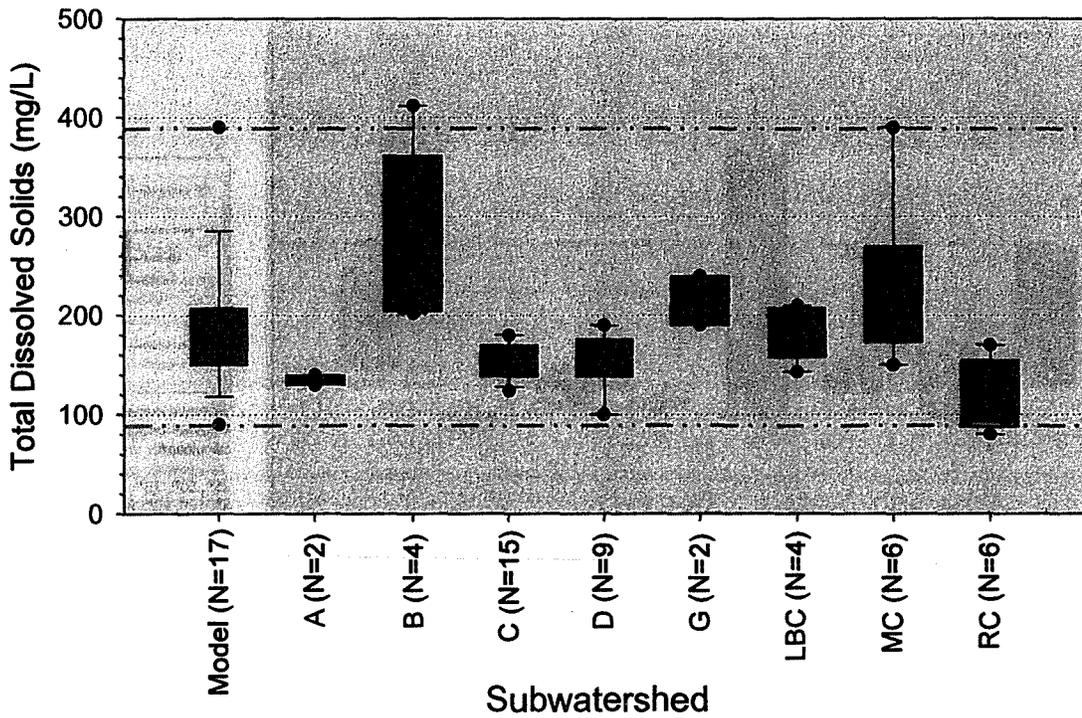
Minimum number of samples required for percentile calculation:

25th, 50th, 75th: N=2
 5th, 10th, 90th, 95th: N = 9

Notes:

Model: All samples used in MLR model;
 LBC: Lucky Bill Canyon;
 MC: Martin Canyon;
 RC: Rustler Canyon;
 See Figure E-1 for Subwatershed delineations and sample location distribution;
 Dashed red horizontal lines represent the range of chemistry values from samples used to develop MLR model;
 10th and 90th percentiles not calculated for subwatershed units with less than 9 samples.

| | |
|---|----------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO SITE-SPECIFIC COPPER TOXICITY MODEL REPORT - APPENDIX E | |
| HARDNESS/ALKALINITY RANGE MEASURED ACROSS STSIU SUBWATERSHEDS | |
| | FIGURE E-6 |



Minimum number of samples required for percentile calculation:

25th, 50th, 75th: N=2
 5th, 10th, 90th, 95th: N=9

Notes:

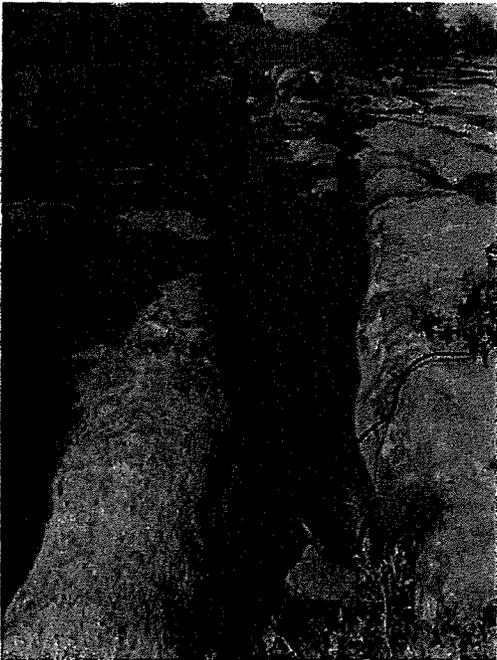
Model: All samples used in MLR model;
 LBC: Lucky Bill Canyon;
 MC: Martin Canyon;
 RC: Rustler Canyon;
 See Figure E-1 for Subwatershed delineations and sample location distribution;
 Dashed red horizontal lines represent the range of chemistry values from samples used to develop MLR model;
 10th and 90th percentiles not calculated for subwatershed units with less than 9 samples.

FREEPORT-MCMORAN CHINO MINES COMPANY
 VANADIUM, NEW MEXICO
SITE-SPECIFIC COPPER TOXICITY MODEL
REPORT – APPENDIX E

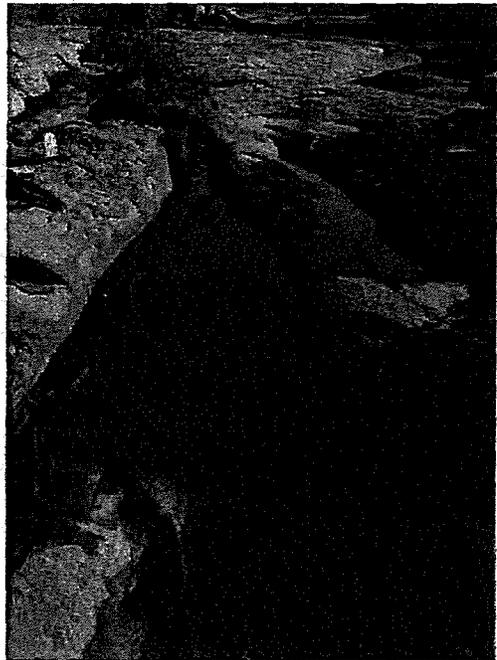
TOTAL DISSOLVED SOLIDS RANGE MEASURED
ACROSS STSIU SUBWATERSHEDS


FIGURE E-7

2013-SW-WER-BD: Photograph #1



2013-SW-WER-BD: Photograph #2



Notes:

Sample ID: 2013-SW-WER-BD
Drainage Description: Drainage C2
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/12/2013
Sample Time: 0915
Maximum Depth: 0.30 m
Maximum Length: 12.19 m
Maximum Width: 1.82 m

| | |
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| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-WER-BD |

2013-SW-WER-5: Photograph #1



2013-SW-WER-5: Photograph #2

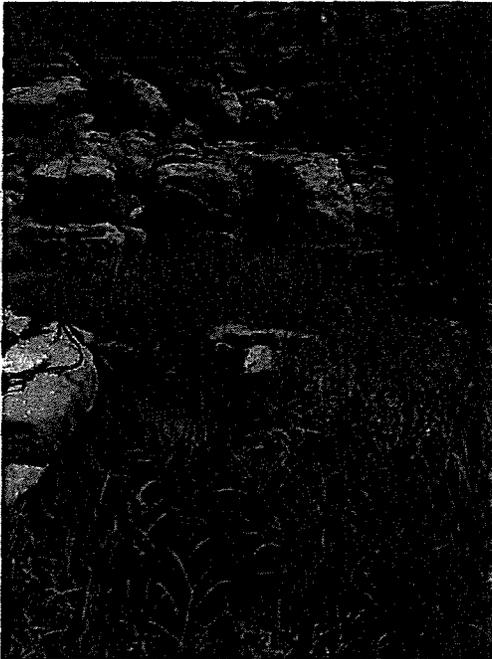


Notes:

Sample ID: 2013-SW-WER-5
Drainage Description: Drainage C1 - Lower
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/12/2013
Sample Time: 1026
Maximum Depth: 0.33 m
Maximum Length: Continuous run
Maximum Width: 6.09 m

| | |
|---|----------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-WER-5 |

2013-SW-C-BS: Photograph #1



2013-SW-C-BS: Photograph #2

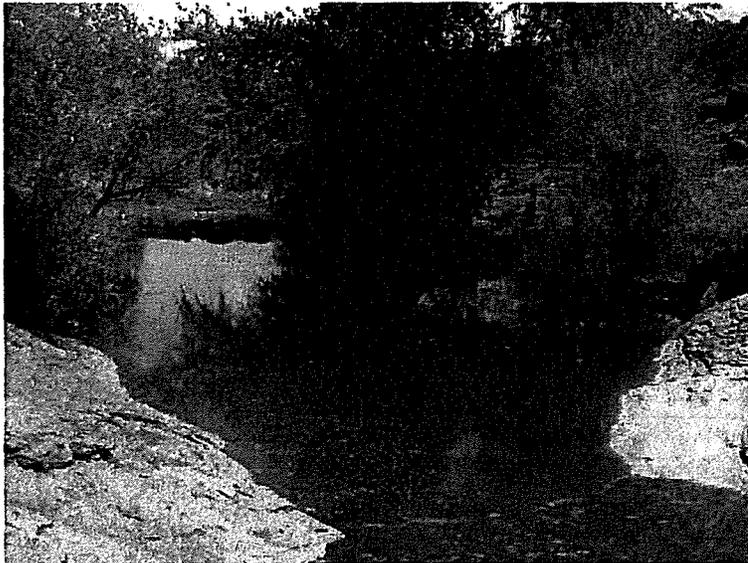


Notes:

Sample ID: 2013-SW-C-BS
Drainage Description: Drainage C1 - BC
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/12/2013
Sample Time: 1235
Maximum Depth: 0.45 m
Maximum Length: Continuous run
Maximum Width: 1.22 m

| | |
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| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-C-BS |

2013-SW-C-BSD: Photograph #1



2013-SW-C-BSD: Photograph #2



Notes:

Sample ID: 2013-SW-C-BSD
Drainage Description: Drainage C1 - BC
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/12/2013
Sample Time: 1312
Maximum Depth: 0.61 m
Maximum Length: Continuous run
Maximum Width: 7.62 m

| | |
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| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-C-BSD |

2013-SW-WER-6: Photograph #1



2013-SW-WER-6: Photograph #2



Notes:

Sample ID: 2013-SW-WER-6
Drainage Description: Drainage C1 - Upper
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/12/2013
Sample Time: 1600
Maximum Depth: 0.23 m
Maximum Length: Continuous run
Maximum Width: 2.74 m

| | |
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| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-WER-6 |

2013-SW-C-BC: Photograph #1



2013-SW-C-BC: Photograph #2



Notes:

Sample ID: 2013-SW-C-BC
Drainage Description: Drainage C1 - BC
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/12/2013
Sample Time: 1700
Maximum Depth: 0.52 m
Maximum Length: Continuous run
Maximum Width: 3.66 m

| | |
|--|--------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-C-BC |

2013-SW-C2-Lower: Photograph #1



2013-SW-C2-Lower: Photograph #2



Notes:

Sample ID: 2013-SW-C2-Lower
Drainage Description: Drainage C2
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/13/2013
Sample Time: 0915
Maximum Depth: 0.18 m
Maximum Length: Continuous run
Maximum Width: 1.92 m

| | |
|--|------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-C2-LOWER |

2013-SW-C2-Upper: Photograph #1



2013-SW-C2-Upper: Photograph #2



Notes:

Sample ID: 2013-SW-C2-Upper
Drainage Description: Drainage C2
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/13/2013
Sample Time: 1020
Maximum Depth: 0.73 m
Maximum Length: Continuous run
Maximum Width: 2.90 m

FREEPORT-MCMORAN CHINO MINES COMPANY
VANADIUM, NEW MEXICO
ATTACHMENT E-1
SITE-SPECIFIC COPPER TOXICITY MODEL REPORT
PHOTO-DOCUMENTATION OF SURFACE WATER
SAMPLES COLLECTED DURING THE 2013 WET SEASON

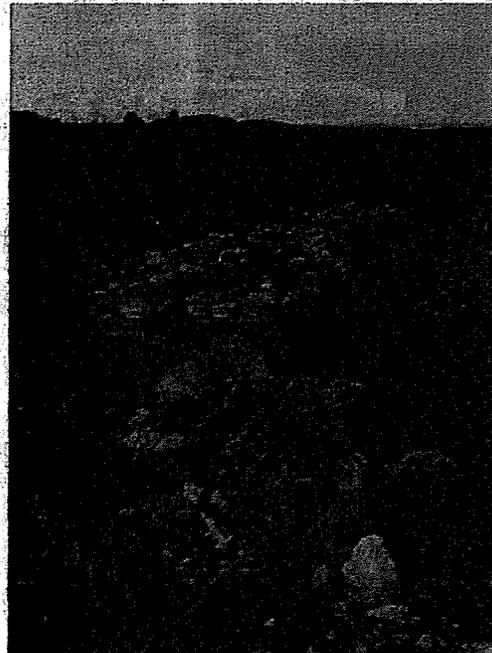


2013-SW-C2-UPPER

2013-SW-BD-Lower: Photograph #1



2013-SW-BD-Lower: Photograph #2



Notes:

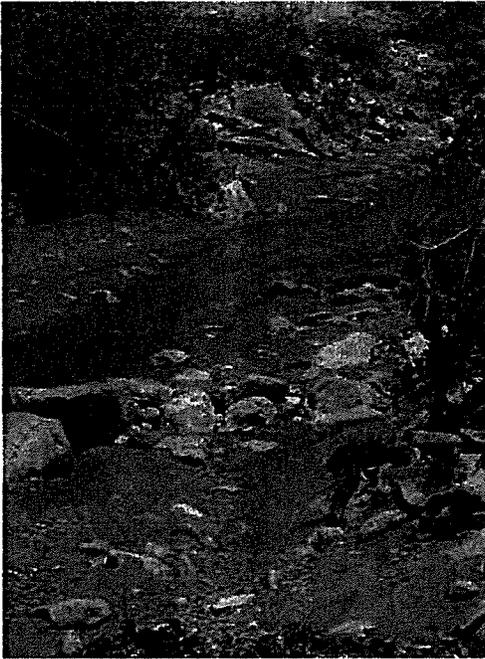
Sample ID: 2013-SW-BD-Lower
Drainage Description: Drainage C2
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/13/2013
Sample Time: 1130
Dry Drainage – No sample collected

| | |
|--|------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-BD-LOWER |

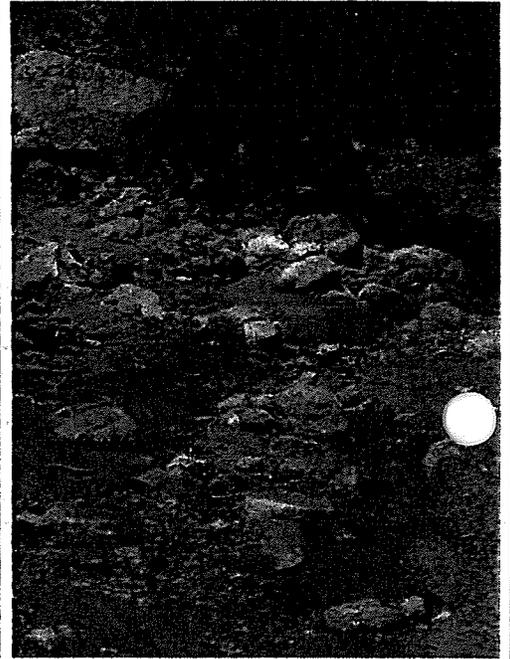
2013-SW-BD-Upper: Photograph #1



2013-SW-BD-Upper: Photograph #2



2013-SW-BD-Upper: Photograph #3



Notes:

Sample ID: 2013-SW-BD-Upper
Drainage Description: Drainage C2
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/13/2013
Sample Time: 1220
Max Depth: 2.5 inches
Residual runoff from storm on 8/12/2013
Dry Drainage – No sample collected

| | |
|--|------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-BD-UPPER |

2013-SW-CDW-1: Photograph #1



2013-SW-CDW-1: Photograph #2



Notes:

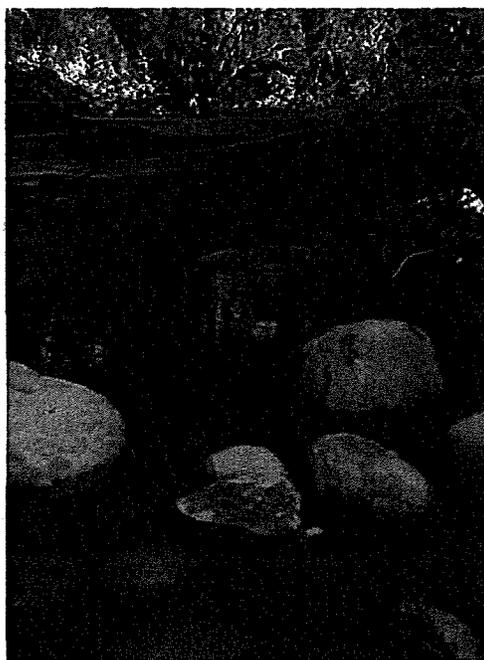
Sample ID: 2013-SW-CDW-1
Drainage Description: Drainage D3
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/13/2013
Sample Time: 1430
Maximum Depth: 0.43 m
Maximum Length: Continuous run
Maximum Width: 3.44 m

| | |
|--|---------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-CDW-1 |

2013-SW-D2: Photograph #1



2013-SW-D2: Photograph #2



Notes:

Sample ID: 2013-SW-D2
Drainage Description: Drainage D2
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/13/2013
Sample Time: 1620
Maximum Depth: 0.21 m
Maximum Length: Continuous run
Maximum Width: 1.86 m

| | |
|--|------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-D2 |

2013-SW-WER-D1-2: Photograph #2



2013-SW-WER-D1-2: Photograph #1



2013-SW-WER-D1-2: Photograph #3

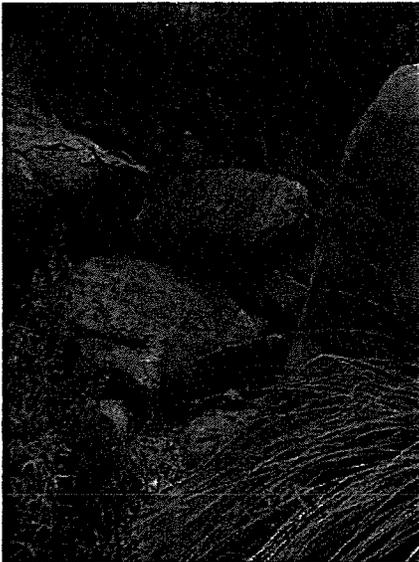


Notes:

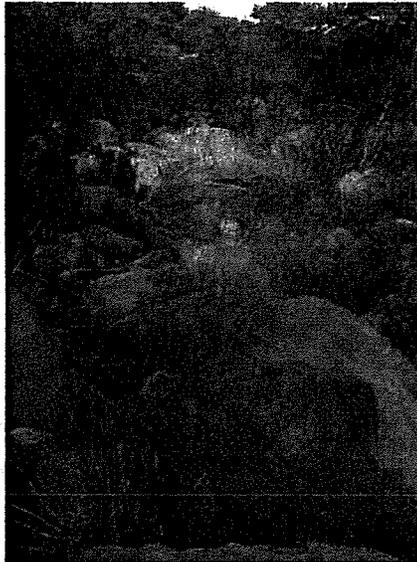
Sample ID: 2013-SW-WER-D1-2
Drainage Description: Drainage D1
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/14/2013
Sample Time: 0820
Maximum Depth: 0.17 m
Maximum Length: 7.32 m
Maximum Width: 5.18 m

| | |
|--|------------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-WER-D1-2 |

2013-SW-D1-BS: Photograph #1



2013-SW-D1-BS: Photograph #2



2013-SW-D1-BS: Photograph #3



Notes:

Sample ID: 2013-SW-D1-BS
Drainage Description: Drainage D1
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/14/2013
Dry Drainage – No sample collected

| | |
|--|---------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-D1-BS |

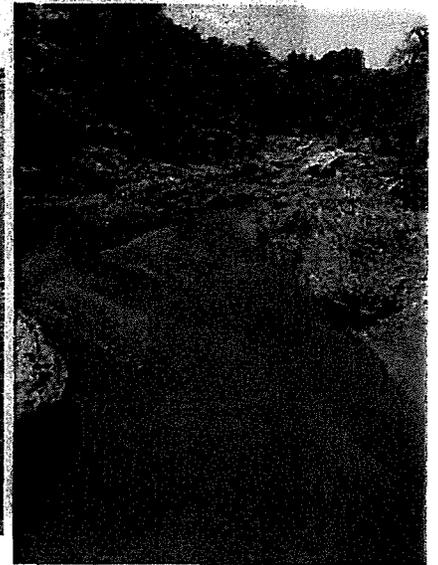
2013-SW-WER-7: Photograph #1



2013-SW-WER-7: Photograph #2



2013-SW-WER-7: Photograph #3



Notes:

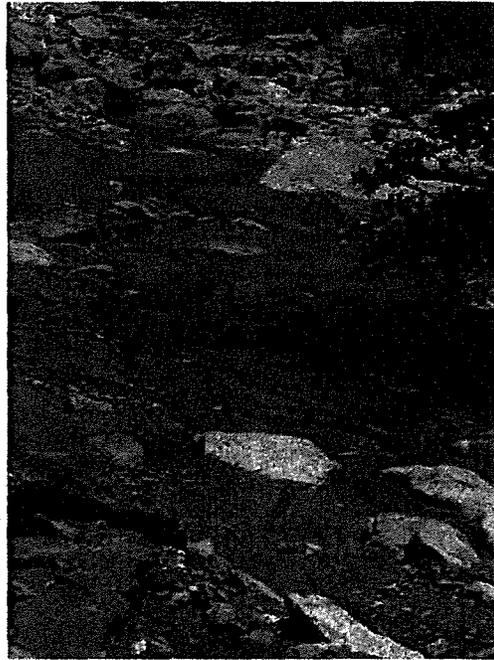
Sample ID: 2013-SW-WER-7
Drainage Description: Drainage B
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/14/2013
Sample Time: 1150
Maximum Depth: 0.55 m
Maximum Length: Continuous run
Maximum Width: 3.11 m

| | |
|--|---------------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-WER-7 |

2013-SW-B: Photograph #1



2013-SW-B: Photograph #2

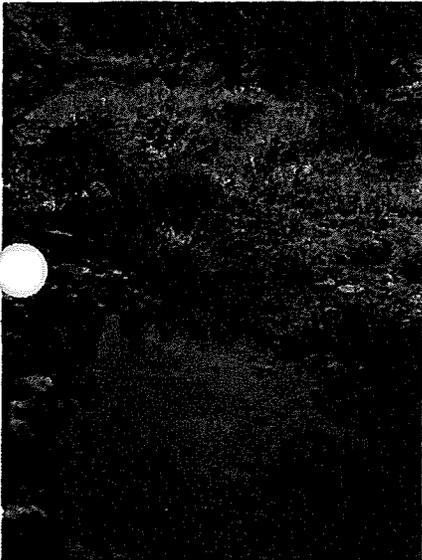


Notes:

Sample ID: 2013-SW-B
Drainage Description: Drainage B
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/14/2013
Sample Time: 1245
Maximum Depth: less than 0.5 inches
Residual runoff from storm on 8/12 – 8/13/2013
Dry Drainage – No sample collected

| | |
|--|-----------|
| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-B |

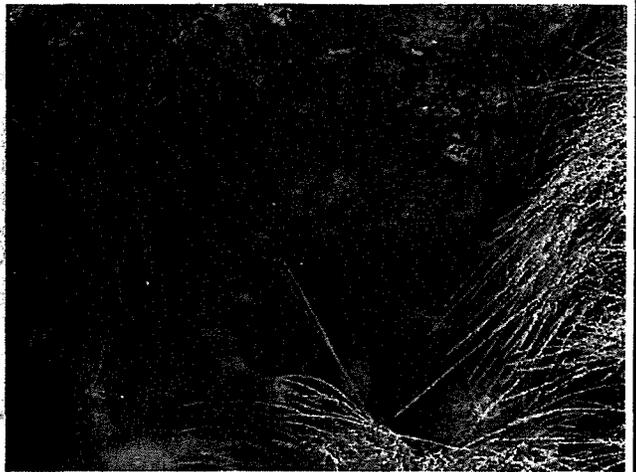
2013-SW-B-AS: Photograph #1



2013-SW-B-AS: Photograph #2



2013-SW-B-AS: Photograph #3



Notes:

Sample ID: 2013-SW-B-AS
Drainage Description: Drainage B
Sample Type: Grab sample for analytical chemistry
Sample Date: 8/14/2013
Sample Time: 1320
Maximum Depth: 0.15 m
Maximum Length: Continuous run
Maximum Width: 1.89 m

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| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO ATTACHMENT E-1 SITE-SPECIFIC COPPER TOXICITY MODEL REPORT | |
| PHOTO-DOCUMENTATION OF SURFACE WATER SAMPLES COLLECTED DURING THE 2013 WET SEASON | |
|  ARCADIS | 2013-SW-B-AS |



Appendix F

**Evaluation of Chiricahua Leopard
Frog Toxicity Data (from Little and
Calfee 2008)**

Appendix F

Evaluation of Chiricahua Leopard Frog Toxicity Data (from Little and Calfee 2008)

This Appendix presents an evaluation of SSC protectiveness to the Chiricahua leopard frog (CLF), which can be found in a limited portion of the STSIU study area. Bolton Spring (Subwatershed C) and Ash Spring (Subwatershed B) and the associated migration pathway between them (Figure E-1) have been designated as critical habitat for the CLF by the USFWS (Federal Register Vol. 77, No. 54, Tuesday, March 20, 2012).

Copper toxicity to the CLF was reported in a 2008 USGS study by Little and Calfee, submitted to the US Fish and Wildlife Service (Little and Calfee, July 2008 Administrative Report). In this study, chronic toxicity tests were initiated with Stage 25 tadpoles during 60-day static renewal exposures to copper. Chronic tests included a control and four copper treatments, with three replicates of three tadpoles (i.e., a total of 9 tadpoles) for each treatment. A 96-hour flow-through test was also performed using five copper concentrations and one control, with four replicates of five tadpoles in each replicate (i.e., a total of 20 tadpoles) for each treatment. The exposures were conducted in a 50 percent mixture of well water and deionized water. Table F-1 and F-2 present the copper toxicity effect concentrations and mean water quality measurements from the acute and chronic toxicity tests.

Table F-1. Summary of CLF copper toxicity endpoints reported in Little and Calfee (2008).

| Measurement endpoint | Copper Effect Concentration (µg/L) |
|--------------------------|------------------------------------|
| 60-day Length LOEC | 47 |
| 60-day Gosner Stage LOEC | 47 |
| 60-day Weight LOEC | 7 |
| 60-day Survival LOEC | 165 |
| 96-hour LC50 | 470 |

Table F-2. Mean water quality parameters (± standard deviation) reported by Little and Calfee (2008) during the 60-day chronic copper exposure and during the 96-hr flow-through acute copper exposure.

| Toxicity Test | DO (mg/L) | Temperature (°C) | pH | Cond. (µS/cm ²) | Alkalinity (mg/L as CaCO ₃) | Hardness (mg/L as CaCO ₃) | NH ₄ (mg/L) |
|-----------------------|----------------|------------------|-----------------|-----------------------------|---|---------------------------------------|------------------------|
| 60-day static renewal | 6.64 (1.33) | 21.28 (0.61) | 8.17 (0.134) | 252 (5.23) | 94.2 (6.70) | 102.9 (8.42) | 0.374 (0.118) |
| 96-hr flow-through | 6.1 (0.5) | 22.0 (0) | 8.5 (0.04) | 252.6 (1.2) | 103.3 (9.7) | 123.4 (9.7) | 0.1 (0.01) |

Concentrations of total organic carbon (TOC) and dissolved organic carbon (DOC) were not measured or reported in this study. However, concentrations of DOC and TOC are assumed to be low (i.e., less than 1 mg/L) because the laboratory dilution water used by Little and Calfee (2008) was a 50 percent mix of groundwater (i.e., well water) and deionized water; and each of these water types are characteristically low in particulate and suspended solids and total and dissolved organic carbon. For a similar mixture of well water and deionized water that was used during the same time period in the same laboratory, Little et al. (2012) assumed (for 2007) and measured (for 2008) DOC concentrations ranging from 0.2 to 0.5 mg/L.

The exposure waters used in the CLF toxicity testing are considered to represent typical laboratory dilution waters and are therefore considered acceptable waters for performing laboratory toxicity tests. However, the exposure waters used in the CLF tests do not represent all of the site-specific water chemistries in STSIU and are thus expected to over-predict copper toxicity to CLF in Site waters. For example, the mean DOC concentration from the 5 surface-water samples that have been collected within and immediately adjacent to the CLF critical habitat is approximately 15 mg/L (range = 13 – 19 mg/L DOC), which is more than an order of magnitude greater than the expected range of DOC concentration in the laboratory water used in the CLF toxicity tests.

The toxicity-modifying properties of the Site water described in this study and incorporated in the proposed WER model should be accounted for when interpreting the CLF toxicity values. Mechanistically, the mitigating properties of Site water described throughout this report should also apply to the bioavailability and toxicity of aqueous copper to other species, including amphibians and thus the CLF, especially the tadpole life stages that were tested by Little and Calfee (2008). The site-specific criteria (SSC) derived in the proposed model approach represents an adjustment to the current hardness-based criteria, wherein the model-predicted water effect ratio (WER) is multiplied by the current hardness-based criteria. Based on guidance concerning application of WERs to derive SSC, there is no reason to use species that occur at the site when determining a WER value (USEPA 1994). Aside from experimental variation, toxicity tests conducted with different species that have similar sensitivities are expected to give similar WERs (USEPA 1994). Because the WER is used to adjust the Criteria Maximum Concentration (CMC; the acute criterion) and/or the Criteria Continuous Concentration (CCC; the chronic criterion), selecting a species or test endpoint that is close to the CMC and/or CCC to which the WER is to be applied is the most important aspect concerning the species, test or endpoint sensitivity used to derive WERs (USEPA 1994; ARCADIS 2013a). This ensures the criteria-adjustment made with the derived WER is protective and applicable to the sensitivity range of the CMC and/or CCC. Use of *Daphnia magna* as the primary test species in the current WER study satisfied this requirement, as described in ARCADIS (2013a).

The protectiveness and applicability of the proposed WER model to the CLF is evaluated below for the acute and chronic toxicity values reported by Little and Calfee (2008).

Evaluation of Acute Copper Toxicity to the CLF

Figure F-1 shows the distribution of acute copper toxicity values used to calculate the current hardness-based copper criteria. This distribution illustrates the range of organism sensitivities to acute copper toxicity and also illustrates how available toxicity data are used to derive the current hardness-based copper criteria. In short, a Genus Mean Acute Value (GMAV) is calculated by taking the geometric mean of all toxicity values available for species within a genus. GMAVs are then ranked from low to high (i.e., "1" for the lowest to "N" for the highest) and the cumulative probability for each GMAV is calculated. The Final Acute Value (FAV) is calculated using the four GMAVs that have cumulative probabilities closest to 0.05. If there are less than 59 GMAVs as in the case with copper, these will always be the four lowest GMAVs. As a result, the derived criterion is intended to protect 95% of a group of diverse genera (USEPA 1985).

As shown in Figure F-1, the current FAV for copper (with represents the 5th percentile of available acute toxicity values) is 14.57 µg/L at a water hardness of 50 mg/L as CaCO₃. Because the acute toxicity values are LC50 concentrations (i.e., the concentration that kills or adversely affects 50 percent of the tested population), the CMC is equal to one-half the FAV (i.e., CMC = FAV / 2). This is done because a

concentration that would adversely affect 50 percent of the 5th percentile (i.e., 50 percent of a sensitive species) is not considered protective (USEPA 1985). Therefore, the current hardness-based copper CMC at a hardness of 50 mg/L as CaCO₃ is 7.4 µg/L.

For comparison purposes, the 96-hour CLF LC50 reported by Little and Calfee (2008) is also shown on Figure F-1. The reported 96-hr CLF median lethal concentration (LC50) of 470 µg/L was normalized to a hardness of 50 mg/L as CaCO₃ by using the copper-criteria hardness slope of 0.9422 in order to compare with other reported acute values. At a hardness of 50 mg/L as CaCO₃, the normalized CLF LC50 is 201 µg/L, which is more than 27-fold greater than the hardness-based CMC. The current hardness-based copper criteria are thus protective of acute toxicity to the CLF. The proposed SSC will also be protective of acute toxicity to the CLF because the toxicity-mitigating properties measured in Site water also apply to other organisms and to the interpretation of the reported CLF values (i.e., the reported CLF acute value is expected to be greater if exposure occurs in Site water).

Evaluation of Chronic Copper Toxicity to the CLF

Some additional background information on application of WERs to derive chronic criteria will be useful to this discussion. As explained in USEPA (1994 and 2001), a WER derived from acute tests is applied to both acute and chronic criteria. The WER value increases as the effect concentration decreases (i.e., WER values increase as the sensitivity of the test increases) because of the effects of strong binding agents such as DOC. Larger WER values are therefore expected for chronic tests than for acute tests. As a result, the WER derived from acute tests is expected to be protective of chronic effects (USEPA 2001).

Chronic toxicity endpoints measured and reported by Little and Calfee (2008) include the lowest observed effect concentrations (LOEC) for the following endpoints: length (47 µg/L), weight (7 µg/L), and Gosner stage (47 µg/L). As described in Calfee and Little (2008), Gosner staging is based on morphological changes that occur during development. The rate of development from one stage to the next is dependent on a variety of physical and ecological factors (including temperature, water quality, nutrition, activity levels, population density, competition, predation, contaminant exposure); therefore, the age of test organisms and their Gosner developmental stage can vary considerably.

The CLF chronic LOECs reported above were determined in exposure water containing a mean hardness of 102.9 mg/L. For reference, the current hardness-based chronic copper criterion at a hardness of 100 mg/L as CaCO₃ is 9 µg/L. This is approximately equal to the most sensitive CLF weight LOEC, and more than 5-fold less than the CLF length and Gosner stage LOECs. Therefore, the hardness-based chronic copper criterion (without adjustments made to account for Site-specific water chemistry) is expected to be protective of CLF developmental stages.

SSC derived from the proposed WER model approach are also expected to be protective of the CLF developmental stages represented by the chronic LOECs reported by Little and Calfee (2008). This conclusion is based on:

Sensitivity of Effect Concentrations: The chronic effect concentrations for CLF length, width and weight compare with the current copper criteria and the sensitivity of the toxicity tests used to develop the WERs. *Daphnia magna* was selected as the test species for WER toxicity tests because it is sensitive at approximately the copper criteria concentrations. Therefore, the proposed WER model is calibrated to

appropriately adjust the current hardness-based copper criteria concentration, which is also within the range and protective of the most sensitive CLF chronic values.

To further illustrate the agreement between the sensitivity of the WER model and the sensitivity of the CLF LOECs, the WER model can be applied to the water chemistry used in the CLF chronic exposures (Table F-1) as described below (based on the steps described in Table 4).

- Using the mean alkalinity of 93 mg/L measured during the 60-day chronic period and an assumed DOC concentration of 0.5 mg/L as input parameters to the Predicted EC50 equation shown in step 1 of Table 3, a predicted *D. magna* LC50 of 14.31 ug/L dissolved Cu is obtained. Although the listed equation specifies an EC50, this value simply represents a given sensitivity as described above. Worth noting is that the predicted EC50 value is only 2 times the 60-day CLF growth LOEC of 7 and is much lower than the length and Gosner stage LOECs of 47 ug/L. As described below, applying the SMAV as the WER denominator provides a margin of safety and will lower the SSC value from this predicted EC50 value.
- Normalized to a hardness of 100 mg/L, this predicted EC50 equals 13.93 ug/L dissolved copper (because the reported mean hardness concentration from the 60-day chronic exposure is 102.9 mg/L).
- The *D. magna* SMAV, which is the selected WER denominator, at a hardness of 100 mg/L equals 19.31 ug/L dissolved Cu. Thus, the predicted WER for the laboratory water used by Little and Calfee (2008) is calculated by dividing 13.93 ug/L by 19.31 ug/L (i.e., sample WER = 13.93/19.31 = 0.7222).
- Therefore, the SSC for the laboratory water used by Little and Calfee (2008) equals the predicted WER (0.722) multiplied by the current copper CCC of 9 ug/L (at a hardness of 100 mg/L): $0.722 \times 9 = 6.49$ ug/L dissolved copper.

This example demonstrates that the proposed WER model, and recommendations for its application, will provide SSC that are protective of CLF developmental stages. The most sensitive CLF chronic effect concentration reported by Little and Calfee (2008) is the 60-day weight LOEC of 7 ug/L copper. When the model is applied to the water chemistry reported in that study (and assuming a range of potential DOC concentration from 0.2 to 0.5 mg/L, as was used for a similar mixture of well water and deionized water in Little et al. 2012), the derived SSC of 3.41 to 6.49 ug/L dissolved copper is protective of this sensitive endpoint, and the other 60-day chronic effects.

Site-Specific Water Chemistry: The mitigating effect of Site-specific water chemistry on copper toxicity has been documented in this report. Because laboratory dilution water used in the CLF studies (i.e., a mixture of deionized water and well water) differs from Site water chemistry, the reported CLF chronic effect concentrations are not expected to reflect Site-specific toxicity values. Instead, based on the strong toxicity-modifying effects of STSIU water chemistry established in this study, copper toxicity is expected to be mitigated significantly relative to the reported CLF effect levels. As stated previously, the high DOC concentrations measured within and adjacent to the CLF critical habitat transect are especially important when considering the toxicity-mitigating properties of Site waters, particularly the surface waters where the CLF is expected to possibly occur (i.e., the CLF critical habitat transect). From a mechanistic perspective, DOC has strong copper-binding properties, which results in the formation of copper-organic carbon complexes that do not readily bind to the receptor site for biotic uptake. In effect, the formation of DOC-

organic carbon complexes decreases the amount of free metal ion, which is the major contributor to aqueous metal toxicity. The laboratory dilution water used in the Little and Calfee (2008) CLF toxicity study is typical of reconstituted water used in laboratory toxicity tests, and therefore represents a highly conservative estimate of toxicity. This concept that water chemistry can modify copper toxicity is described throughout the report, including a summary of the current scientific understanding of copper toxicity mechanisms and empirical measurements made in Site water.

It is also necessary to evaluate the study design and possible uncertainties related to the reported CLF effect concentrations to provide additional context to this protectiveness evaluation. This evaluation is provided below.

Evaluation of Copper Toxicity Test Design and Interpretation of Results

Evaluating aspects of the study design described in Little and Calfee (2008) is important to ensure that any interpretation or application of results on a site-specific basis is technically-sound and minimizes possible uncertainties. The intent here is not to criticize the quality of this study, but to understand possible uncertainties that might be associated with the reported effect concentrations. This is necessary in order to evaluate the protectiveness of the proposed WER model approach to the sensitivity of the CLF to copper toxicity. The current understanding of the CLF sensitivity to copper is based entirely on the Little and Calfee Administrative Report (2008) because no other study reports copper toxicity to the CLF. A technical review of this Administrative Report follows.

Acute Toxicity Test: The acute copper toxicity tests (96-hour flow through exposure) performed by Little and Calfee (2008) appears to have been conducted in general accordance with American Society for Testing and Materials (ASTM) acute toxicity protocol, as described by the study authors. This study design provided sufficient replication of copper treatments, with four replicates of five tadpoles per treatment (treatments included five copper concentrations and one control). This provides a total of 20 tadpoles per tested concentration, which is consistent with the required minimum for performing such tests. However, the 96-hour LC50 concentration appears to be based on nominal exposure concentrations, because the report does not specify or present measured copper concentrations for this acute test. In general, metal-toxicity studies that do not report measured concentrations are not considered of high enough quality for inclusion in criteria-derivation calculations.

Chronic Toxicity Test (60-day Static Renewal Exposure)

The most sensitive CLF copper effect concentrations were derived from the 60-day static renewal exposure test. "Static-renewal" refers to a test method in which the exposure solutions are renewed with fresh exposure solutions at specific intervals throughout the duration of the test. In the 60-day copper CLF study conducted by Little and Calfee (2008), exposures were renewed twice weekly over the 60-day exposure period. An evaluation of specific study design components from the 60-day static renewal exposure tests follows.

Replication and Sample Size: The replication and sample size of the 60-day copper exposure tests was limited to only three replicates per concentration with three tadpoles per replicate (for a total of nine tadpoles per tested concentration). This level of replication is less than what is typically required for a definitive toxicity test and can thereby limit the confidence of derived effect concentrations. However, it is recognized here that the CLF is federally-listed as a threatened species and therefore organism availability was likely limited for performing the toxicity tests. As stated above, a minimum of 20 organisms per tested

concentration is usually preferred as the minimum number of organisms when performing definitive toxicity tests.

Analytical Measurements: The 60-day copper exposure test included only a limited number of analytical measurements. As described previously, DOC concentrations were not measured in dilution water (although measured DOC concentrations are available from the same period of time in the same laboratory).

An important point to consider when interpreting the 60-day effect concentrations is the frequency of analytical copper measurements. Over the course of the 60-day exposure to copper, metals were measured in the exposure solutions only twice – following 30 and 60 days of exposures. The average of these two values was used to compute the actual copper exposure concentrations. This is important because the reported effect concentrations are directly based on the measured copper concentrations. Significant uncertainty could therefore be introduced towards the actual effect concentrations, as described in more detail below.

The report states that: exposure solutions were renewed twice weekly; tadpoles were fed 12 hours before each water change; and water samples were collected for copper analysis at the end of the 30-day and 60-day exposure period. Thus, copper concentrations were not measured in the fresh exposure solutions, but were instead measured at the end of an exposure period (i.e., following days 30 and 60) after feeding occurred. This has important implications for interpreting the reported copper effect concentrations because the method used for copper analysis (i.e., the frequency and timing of measurements) likely underestimates the actual exposure concentrations. Specifically, the concentration of aqueous copper in solution is expected to decrease following feeding because copper adsorbs to food particulate matter (food in this study consisted of gelatin cubes of crushed algae discs, fish flakes, cucumber, and calcium powder), thereby decreasing the amount of aqueous copper in solution. Table 14 in Calfee and Little (2008) shows the nominal and measured copper concentrations from the 60-day study; measured concentrations were always less than nominal. For the reported copper LOEC concentrations (i.e., 7 µg/L for weight, 47 µg/L for length and Gosner stage, and 165 µg/L for mortality), the measured concentrations were only 16 to 25 percent of the nominal concentrations, which suggests that copper decreased towards the end of an exposure period (when copper was measured) and/or the preparation of the copper stock solution or dosing of the stock solution to exposure chambers was inaccurate. With static renewals performed twice weekly over a 60-day exposure period, this equals about 18 separate renewals of the exposure solution but copper was measured only twice during this exposure period. As a result, there is considerable uncertainty regarding the range of exposure concentrations (and therefore considerable uncertainty about the accuracy of these reported effect concentrations). Assuming preparation of the stock solutions and copper dosing were accurately performed, this would indicate copper concentrations at the beginning of a renewal exposure period were approximately 4 to 6 times greater than the copper concentrations measured following a renewal exposure period (i.e., when water samples were collected for copper analysis). As a consequence, the toxicity of copper to CLF tadpoles might be approximately 4 to 6 times less than the reported effect concentrations indicate.

Metal Fraction Measured: Although not specifically reported by the study authors, we assume measured copper concentrations represent the dissolved fraction. Even if total recoverable copper concentrations were measured, it is probably safe to assume that dissolved and total recoverable concentrations were approximately equal because these tests were performed using a mixture of groundwater and deionized

water (both of which should have contained low concentrations of particles [for groundwater] or no particles [for deionized water]).

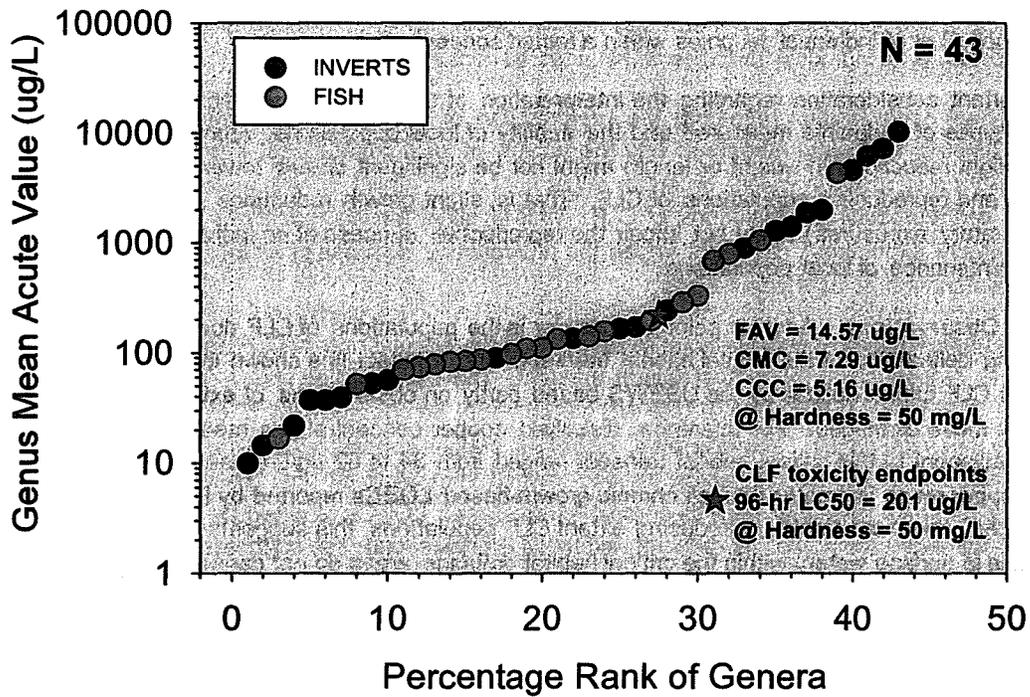
Growth-Based Endpoint Measurements: For weight and length measurements, sufficient data are not reported to determine weight and length variability of organisms used at test initiation. Those initial weights and lengths are needed to understand whether there were any differences in the size of tadpoles at test initiation across the treatments. This is likely not a crucial issue, but could influence the results if size differences existed between treatments. Additionally, it is unclear whether the weights listed in Table 13 of Little and Calfee (2008) represent the mean and standard deviation of the replicates (i.e., total biomass of surviving tadpoles) or of individual tadpoles within a tested concentration.

Another important consideration regarding the interpretation of these effect concentrations is the linkage between the types of endpoints measured and the viability of local populations. From a population standpoint, slight reductions in weight or length might not be significant drivers towards maintaining locally viable and reproducing populations of CLF. That is, slight growth reductions (represented by the reported laboratory exposures) might not impair the reproductive success of an individual, which is likely key to the maintenance of local populations.

CLF Survey Observations: Another point to consider is the populations of CLF documented by the USFWS during delineation of the critical habitat transect. The transect line shown in Figure E-2 was delineated as CLF critical habitat by the USFWS based partly on observations of extended CLF occurrence in these drainages. For reference, dissolved copper concentrations measured within and immediately adjacent to this critical habitat transect ranged from 34 to 62 $\mu\text{g/L}$ (based on 5 samples; Table E-3). This copper range is greater than all chronic growth-based LOECs reported by Little and Calfee (2008). Provided these are viable, reproducing extant CLF populations, this suggests that copper concentrations in surface waters within the critical habitat drainage areas do not cause adverse reproductive or population effects. The findings from this report regarding Site-specific copper toxicity support this observation.

Summary

In summary, the proposed WER model approach will provide conservative SSC that will be protective of the CLF, because STSIU water chemistry parameters should modify the toxicity of copper to CLF in the same manner as they modify the toxicity of copper to fish and other aquatic organisms. Beyond that margin of safety, the uncertainty about the accuracy of chronic-growth-effect concentrations reported by Little and Calfee (2008) possibly contributes additionally to an over-prediction of copper toxicity to CLF. Therefore, the CLF chronic-toxicity results reported by Little and Calfee (2008) should be interpreted with caution and should not be used to derive site-specific criteria for STSIU waters.



Notes:

FAV = Final Acute Value
 CMC = Criteria Maximum Concentration
 CCC = Criteria Continuous Concentration
 CLF = Chiricahua leopard frog (96-hr LC50 calculated from Little and Calfee 2008)
 Hardness-normalization performed using copper-criteria hardness slope of 0.9422

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| FREEPORT-MCMORAN CHINO MINES COMPANY VANADIUM, NEW MEXICO SITE-SPECIFIC COPPER TOXICITY MODEL REPORT – APPENDIX F | |
| SPECIES SENSITIVITY DISTRIBUTION OF ACUTE TOXICITY VALUES USED TO DERIVE THE CURRENT NEW MEXICO COPPER CRITERIA | |
| | FIGURE F-1 |

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 LANDSCAPEBARRY A. FULTON* and JOSEPH S. MEYER
ARCADIS US, Lakewood, Colorado, USA

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Abstract: The water effect ratio (WER) procedure developed by the US Environmental Protection Agency is commonly used to derive site-specific criteria for point-source metal discharges into perennial waters. However, experience is limited with this method in the ephemeral and intermittent systems typical of arid climates. The present study presents a regression model to develop WER-based site-specific criteria for a network of ephemeral and intermittent streams influenced by nonpoint sources of Cu in the southwestern United States. Acute (48-h) Cu toxicity tests were performed concurrently with *Daphnia magna* in site water samples and hardness-matched laboratory waters. Median effect concentrations (EC50s) for Cu in site water samples ($n = 17$) varied by more than 12-fold, and the range of calculated WER values was similar. Statistically significant ($\alpha = 0.05$) univariate predictors of site-specific Cu toxicity included (in sequence of decreasing significance) dissolved organic carbon (DOC), hardness/alkalinity ratio, alkalinity, K, and total dissolved solids. A multiple-regression model developed from a combination of DOC and alkalinity explained 85% of the toxicity variability in site water samples, providing a strong predictive tool that can be used in the WER framework when site-specific criteria values are derived. The biotic ligand model (BLM) underpredicted toxicity in site waters by more than 2-fold. Adjustments to the default BLM parameters improved the model's performance but did not provide a better predictive tool compared with the regression model developed from DOC and alkalinity. *Environ Toxicol Chem* 2014;33:1865–1873. © 2014 SETAC

Keywords: Biotic ligand model Multiple regression Southwestern United States Water chemistry Water effect ratio

INTRODUCTION

The ambient water quality criteria for Cu currently applied by all states in the United States are based on a relationship between water hardness and metal toxicity to aquatic organisms, as determined by toxicity tests conducted in mostly synthetic laboratory waters. However, the federal water quality standards regulation provides states with the option to calculate site-specific criteria for Cu based on the well-established principle that the exposure-water chemistry (e.g., pH, alkalinity, hardness, and dissolved organic carbon [DOC] concentration) modifies the toxicity of cationic metals to aquatic organisms [1]. The water effect ratio (WER) procedure (see explanation of WER calculations below) is a federally approved site-specific criteria method [2,3] used to account for the toxicity-modifying properties of ambient surface waters. In addition, some states allow determination of site-specific criteria using the biotic ligand model (BLM; see explanation of the model in the *Biotic ligand model* section). Despite relatively widespread use for point-source discharges of Cu into perennial streams and rivers, the use of WER studies and BLM calculations to derive site-specific criteria for nonpoint-source discharges of Cu into intermittent and ephemeral surface waters, which are common in arid climates, is limited. Therefore, reliable approaches are needed to address such nonstandard situations.

The BLM is a computerized model that predicts the toxicity of Cu to several freshwater species of aquatic invertebrates and

fish and thus is convenient to use because of time and cost savings, compared with the extensive toxicity testing required for WER-based site-specific criteria. The BLM is the US Environmental Protection Agency's (USEPA's) current recommended method for deriving national water quality criteria for Cu [4], because it incorporates a wider range of water chemistry parameters (pH, alkalinity, and concentrations of major inorganic ions and DOC) than only water hardness and thus predicts toxicity more accurately. However, none of the states in the United States have yet adopted the BLM as the primary method to calculate ambient water quality criteria for Cu. Instead, hardness-based equations are still used to derive Cu criteria, although many of the states have incorporated the BLM into their administrative code in some form as an option for deriving site-specific criteria.

Despite the ease of use and the time and cost savings the BLM provides, the default calibration of the BLM can leave uncertainty about the accuracy of its predictions of Cu toxicity for a given strain of invertebrate or fish and/or for a given type of DOC. For example, it is unknown whether the affinity and binding-site density for Cu by DOC in surface waters in arid climates differ from DOC in more mesic climates. Therefore, theoretically, a WER test can more accurately determine site-specific criteria for a given water sample than can the BLM. However, WER testing is most amenable for determining site-specific criteria for point-source discharges instead of for all combinations of spatial and temporal variability in a large number of water bodies. Furthermore, current WER guidelines [2,3] are based on experience in perennial rather than ephemeral systems.

The WER procedure compares empirical toxicity endpoints, such as median lethal effect concentrations (EC50s) measured in

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* Address correspondence to Barry.Fulton@arcadis-us.com
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site waters, with the same toxicity endpoint measured in hardness-matched laboratory waters [2,3]:

$$\text{WER} = \frac{\text{site-water EC50}}{\text{laboratory-water EC50}} \quad (1)$$

Because synthetic laboratory waters used in the WER procedure are assumed to represent water chemistry and toxicity conditions from which the hardness-based ambient water quality criteria were calculated (and this assumption is verified in the WER procedure by comparisons with other studies [2]), WER values greater than 1.0 indicate protective effects of site-specific water chemistry on metal toxicity (beyond the protective effect of hardness that is already accounted for in the hardness-matched laboratory water). Using the WER procedure, a site-specific criterion is the product of a measured WER value and the corresponding hardness-matched ambient water quality criterion [2,3].

Despite the assumed accuracy of a WER value determined for a given water sample, spatial and temporal variability in water chemistry can lead to spatial and temporal variability in WER values. This presents a challenge for site-specific criteria development because of the possible over- or underprotection that can result from a WER-adjusted site-specific criteria value, particularly when no specific mechanistic or statistical underpinning for the variability can be identified based on the WER toxicity tests. Many arid landscapes, such as those in parts of the western United States, contain intermittent and ephemeral water bodies impacted by naturally occurring or anthropogenic nonpoint sources. As a consequence, current WER guidance might need to be modified for application to arid landscapes and ephemeral aquatic systems, because spatial and temporal characteristics of water persistence and water chemistry in such landscapes can differ from perennial systems.

In the present study, the WER framework was used to develop a regression model to predict site-specific Cu toxicity in multiple ephemeral and intermittent surface waters that receive nonpoint sources of Cu in an arid landscape in the southwestern United States. Empirical measures of Cu toxicity were determined in *Daphnia magna* acute lethality tests and evaluated through correlation and step-wise multiple-regression analyses to identify the primary chemical predictors of Cu toxicity in the site waters. The regression model was then incorporated into an equation that can be used to predict the WER value in a variety of water chemistries that might occur in the multiple-watershed study area, thereby allowing derivation of site-specific criteria for any of those receiving waters. Performance of the BLM was also evaluated as an additional tool for developing site-specific criteria for Cu.

MATERIALS AND METHODS

Site description

The study area extends across an approximately 60-km² arid, mountainous region of the southwestern United States. Elevations range from approximately 1500 m above sea level in the lowlands (comprising desert grasslands and shrub lands) to 2300 m above sea level in the mountainous terrain. There is diffuse Cu contamination to the adjacent landscape as a result of historical industrial emissions and natural mineralized soil. The study area was categorized into a total of 9 sub-watersheds that encompass 12 drainages. The surface waters are mostly ephemeral, flowing only in direct response to high-intensity precipitation that occurs over short durations, primarily during mid to late summer (i.e., southwestern monsoonal precipitation events).

Following these precipitation events, surface water can persist in isolated pools for short periods of up to several weeks. These short-term pools are generally located in headwaters, where drainage channels are comprised primarily of bedrock and stable substrate. Water chemistry varies among the sub-watersheds because of localized differences in geology, geomorphology, hydrology, and surrounding upland landscapes.

Sample collection

Surface-water samples were collected from as many sub-watersheds as possible, limited by the presence of rainfall pools and seeps. A total of 18 surface-water samples were collected for chemical analyses and toxicity tests twice during summer 2011 (12 locations in August and 6 repeat samples in September from locations also sampled in August). No measurable flow was observed in these drainages during the 2 rounds of sampling, and most of the drainage areas surveyed during each field sampling round were dry. All surface-water samples were collected from pool habitats that were relatively isolated in terms of their connectivity to up-gradient or down-gradient drainage areas.

Samples were collected and processed in accordance with USEPA guidelines [2], including the use of clean techniques for all phases of field sampling, such as equipment preparation, water collection, handling, and storage. Each water sample was collected as a grab sample taken at approximately the center or the deepest section of the pool, and at mid-depth. Before collecting a water sample, the acid-rinsed, low-density polyethylene sample container was filled with water and shaken to rinse the container; this process was repeated for a total of 3 rinses for each sample container. The screw caps on the sample containers were sealed so no air space remained inside the container. Immediately after sample collection, the containers were chilled and stored in coolers for transport to the testing laboratory. Samples were shipped the same day as collected, and all samples arrived at the laboratories within 24 h of collection. Samples were maintained at <4 °C in the dark until test initiation.

Laboratory dilution water

Reconstituted laboratory dilution water was prepared by adding reagent-grade salts to 18-M Ω deionized water according to USEPA guidelines [5]. Hardness of laboratory dilution waters was matched in concentrations to water hardness of site samples according to WER testing requirements [2]. This included equal or lower water hardness in matched laboratory water, unless the hardness of a site water sample was less than 50 mg/L as CaCO₃. All laboratory water tests were performed at water hardness concentrations within the WER guideline-required range of 40 mg/L to 220 mg/L as CaCO₃ [2]. In total, 11 laboratory dilution waters were used for the WER toxicity tests, with hardness ranging from 42 mg/L to 168 mg/L as CaCO₃ and alkalinity concentrations ranging from 30 mg/L to 112 mg/L as CaCO₃. The laboratory dilution water used for all toxicity tests was comparable to waters used to develop the hardness-based Cu ambient water quality criteria, including having alkalinity similar to hardness, approximately circumneutral pH, and low concentrations of total suspended solids (<5 mg/L) and total organic carbon (TOC; <1 mg C/L; Supplemental Data, Tables S1 and S2).

Toxicity testing

To investigate the influence of site water chemistry on Cu toxicity, standard WER tests were conducted [2]. Laboratory water toxicity tests were performed concurrent with site water

toxicity tests under identical exposure conditions (except tested Cu concentrations). Acute toxicity tests were performed with neonates (<24 h old) of the freshwater cladoceran *D. magna* obtained from Aquatic Biosystems, using the USEPA-recommended protocol [5]. *Daphnia magna* was chosen for these toxicity tests because they are a USEPA-recommended species for WER testing [2,3] and a substantial database is available to compare Cu toxicity in the laboratory waters used in the present study with results in other laboratories, as required in the WER guidelines [2,3]. All cultures and toxicity tests were performed in a temperature-controlled growth chamber at 20 ± 1 °C with a 16:8-h light:dark cycle. Cultures were maintained in moderately hard reconstituted water [5] and fed a combination of yeast–trout chow (YTC; Cerophyll™) and the green alga *Pseudokirchneriella subcapitata*.

Neither the *D. magna* neonates nor their mothers were acclimated to the hardness of the water in which the neonates were tested, because the water hardness of any given site water (and thus of its required hardness-matched laboratory water) was not known a priori. The streamlined Cu guidance for WER tests specifies that site water holding time should not exceed 96 h before a WER test is started [3], thus making it difficult to acclimate organisms to an unknown water hardness and still start the WER toxicity test in time. Therefore, the WER guidance states that “Acclimation to site water is desirable but optional” (p 7 in USEPA [3]) and that “The least objectionable approach is to acclimate the organisms to a laboratory dilution water with a hardness in the range of 50 to 150 mg/L and then use this water as the laboratory dilution water when the WER is determined” [2], which was done in the present study. The potential influence of this lack of acclimation on the toxicity of Cu to *D. magna* (or other aquatic invertebrates) is unknown; and even for fish, the influence of acclimation depends on the species and metal tested [6]. However, because the hardness of the laboratory water was matched to the hardness of the site water for each site water and the WER value is the ratio of the EC50 values in the site water and the hardness-matched laboratory water, the relative effect on the WER of not acclimating the test organisms to the site water hardness might have been minimized.

Test solutions were not renewed and organisms were not fed during the 48-h exposure period. Each test treatment consisted of 4 replicate polyethylene chambers, each containing 25 mL of test solution and 5 organisms. Including controls (unspiked site or laboratory water), 6 Cu concentrations were tested for each site and laboratory water sample. Copper stock solutions used to spike test treatments were prepared by dissolving $\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$ in deionized water. A separate stock solution was prepared for each round of WER testing, but the same stock solution was used to spike all laboratory and site waters in each round of testing. Copper concentrations were selected for each site water sample based on the results of 24-h static range-finding toxicity tests performed on receipt of each sample and were a series of nominal $0.7\times$ dilutions of a high concentration that was expected to produce approximately 100% mortality in 48 h. Exposure waters were mixed thoroughly and allowed to stand for a minimum of 20 h at 4 °C before test initiation to allow the metal chemistry to equilibrate, as recommended by the USEPA [3] and Ma et al. [7]. Aliquots of exposure water were collected from a replicate chamber in each treatment for Cu analyses at the beginning and end of each test. The observation endpoint was immobilization; thus, toxicity results are reported herein as EC50 values instead of median lethal concentrations (LC50s). A toxicity test was acceptable if mortality in the hardness-matched laboratory water control was $\leq 10\%$.

Chemical analyses

Water chemistry parameters measured in all tests included dissolved oxygen, pH, conductivity, temperature, hardness, alkalinity, DOC, Cu, and major inorganic ions (Ca^{2+} , Mg^{2+} , Na^+ , K^+ , Cl^- , SO_4^{2-}). All parameters were measured on samples collected at test initiation. Physicochemical parameters (dissolved oxygen, pH, conductivity, and temperature) also were measured at 24 h in a replicate chamber in each treatment.

Concentrations of Al, Cd, Cu, Fe, Mn, Pb, and Zn in the site waters and total recoverable and dissolved Cu concentrations at the beginning and end of each site water and laboratory water toxicity test were determined by inductively coupled plasma mass spectroscopy (ICP-MS), according to USEPA method 200.8 (Agilent Technologies 7500ce series, with an Octopole Reaction System). For dissolved-metal concentrations, samples were filtered through a 0.45- μm nylon membrane filter (EMD Millipore) following prerinses with ultrapure deionized water and then sample water. Samples collected for metals were preserved with trace metal-grade nitric acid immediately after collection (total recoverable concentrations) or after filtration (dissolved concentrations). Internal laboratory blank samples and certified standards were analyzed at a rate of 1 per 10 samples, with acceptance criteria of $\pm 10\%$ of the known concentration in the continuing calibration verifications. Concentrations of major cations (Ca^{2+} , Mg^{2+} , Na^+ , and K^+) were determined by ICP-MS, according to USEPA method 200.7. Concentrations of the anions Cl^- and SO_4^{2-} were determined by low-level amperometric titration (Standard Methods 4500-E) and the turbidimetric method (D516-07), respectively.

All site waters were analyzed for DOC and TOC concentrations, but laboratory water samples inadvertently were analyzed only for TOC concentration. Samples for DOC analyses were filtered through a 0.45- μm nylon membrane filter after a 20-mL rinse with sample water, acidified with nitric acid, and stored in amber glass bottles at 4 °C. Dissolved organic carbon and TOC concentrations were determined by direct combustion/infrared detection using a Leco SC632 sulfur/carbon analyzer calibrated with a certified potassium hydrogen phthalate standard (Fisher Scientific); the method detection limit was 1 mg C/L.

Data treatment

The 48-h EC50s for immobilization/death and their 95% confidence limits were computed by maximum likelihood probit analysis using ToxCalc™ statistical software (Ver 5.0; Tidepool Scientific). Copper concentrations used to calculate EC50 values were the averages of Cu determined at the beginning and end of each test. To evaluate the influence of individual water chemistry parameters on Cu toxicity, univariate linear-regression analyses ($\alpha = 0.05$) were performed using measured dissolved Cu EC50 values and measured water chemistry parameters. With the exception of pH, all data were log-transformed for univariate and multivariate regression analyses. Step-wise, multiple linear regression analyses were performed to determine the best combination of water chemistry parameters for predicting measured Cu toxicity. Models were evaluated for predictive ability (based on the adjusted R^2 [i.e., the percentage of variance in the EC50s that is explained by the regression] and p values) and by limiting the collinearity of water chemistry parameters (evaluated by inspection of the variance inflation factor). All regression analyses were performed using SigmaPlot™ software (Ver 12.1; SYSTAT Software).

Water effect ratios

Water effect ratios were calculated as the Cu EC50 measured in site water divided by an appropriate denominator (e.g., Equation 1). For each sample, a set of 4 WER values was calculated based on 4 different denominators that potentially could be used, including individual hardness-matched laboratory water EC50 values, the USEPA-recommended species mean acute value (SMAV) for *D. magna* [3], a recalculated *D. magna* SMAV based on excluding nominal Cu concentrations from the toxicity dataset listed in the USEPA [3], and the geometric mean of the concurrent hardness-matched laboratory water EC50 values. Based on USEPA guidance [2], laboratory water Cu EC50 values were compared with results from other laboratories to evaluate the sensitivity range of the laboratory water EC50 values. In the more recent Cu WER guidance [3] designed for point-source discharge of Cu, the WER denominator is the greater of the laboratory water EC50 or the SMAV for the test species. The USEPA-recommended *D. magna* SMAV for dissolved Cu at a hardness of 100 mg/L as CaCO₃ is 19.31 µg Cu/L (Appendix B in USEPA [3]). Although the present study site does not receive point-source Cu discharges, the *D. magna* SMAV was used as the WER denominator if concurrent laboratory water EC50 values normalized to a hardness of 100 mg/L were less than 19.31 µg/L dissolved Cu. All EC50-hardness normalizations were performed using the hardness-based Cu criteria slope of 0.9422 [8].

Biotic ligand model

The influence of site-specific water chemistry on acute Cu toxicity was also evaluated using the Cu BLM (Ver 2.2.3; http://hydroqual.com/wr_blm.html). Concentrations of pH, alkalinity, DOC, Ca²⁺, Mg²⁺, Na⁺, K⁺, Cl⁻, and SO₄²⁻ measured in toxicity-test exposure solutions were used as the BLM input parameters. Recommended default values for the percentage of humic acid (10%) and sulfide (0.01 µM) were also used as BLM input parameters. The BLM was run in toxicity mode to produce BLM-predicted EC50 values, for comparison with measured and regression model-predicted EC50 values. Because TOC concentrations in the laboratory waters were below the method detection limit (1 mg C/L), a DOC concentration of 0.5 mg C/L was assumed for BLM calculations with the laboratory waters; however, that assumption has uncertainty associated with it because the DOC concentration in deionized laboratory waters can vary. Therefore, we performed a sensitivity analysis by also conducting the BLM calculations for the laboratory waters using lower and upper bounds on the assumed DOC concentration of 0.3 mg C/L and 0.7 mg C/L.

RESULTS AND DISCUSSION

Chemical analyses of the hardness-matched laboratory waters and the site waters (except for metals other than Cu) are listed in Supplemental Data, Tables S1 and S2. Measured dissolved Cu concentrations ranged from 40% to >99% of nominal, and measured total Cu concentrations ranged from 56% to >99% of nominal. Concentrations of other metals in the site waters are listed in Supplemental Data, Table S3.

With the exception of site water sample 1-5, at least 90% of organisms survived in control treatments of all laboratory and site water toxicity tests. Only 20% of organisms survived in the unspiked control for sample 1-5, which precluded calculation of EC50 and WER values for this sample. Therefore, that sample was excluded from the subsequent regression analyses that are discussed below.

Laboratory water tests

To verify the sensitivity of tested organisms, the Cu EC50 values from laboratory water tests were compared with the 55 *D. magna* EC50 values listed in Appendix B of the streamlined WER guidance document [3], which were used to compute the SMAV of 19.31 µg/L dissolved Cu (i.e., the recommended WER denominator). Of the 55 *D. magna* EC50 values listed in by the USEPA [3], 45 were based on measured Cu concentrations and 10 were based on nominal Cu concentrations. Laboratory water EC50 values determined in the present study were comparable to all EC50s used to calculate the *D. magna* SMAV but were more similar to the measured EC50s (Supplemental Data, Figure S1). In addition, the geometric mean of hardness-normalized laboratory water toxicity tests (13.95 µg/L at a hardness of 100 mg/L as CaCO₃) determined in the present study was within a factor of 1.4 of the recommended *D. magna* SMAV and within a factor of 1.2 of the geometric mean of only the measured EC50 values from the streamlined WER guidance document (16.50 µg/L [3]). The slope between $\ln[\text{dissolved Cu EC50}]$ and $\ln[\text{hardness}]$ for *D. magna* in the present study (1.189 for hardness values ranging from 42 mg/L to 168 mg/L as CaCO₃) was slightly greater than the pooled slope used in the hardness-based acute Cu criteria (0.9422), but it is within 13% of the slope calculated using only the *D. magna* values listed in the historic USEPA hardness-based Cu criteria documents (1.044 for hardness values ranging from 45 mg/L to 226 mg/L as CaCO₃ [8]). Overall, these results suggest that the sensitivity of test organisms used in the present study was comparable to previously reported laboratory water results and therefore was acceptable for determining WER values.

Water effect ratios

All but 1 of the 17 calculated WER values were greater than 1.0, using the SMAV as the WER denominator (range of WER values = 0.989–14.41; Table 1). The preponderance of WER values greater than 1.0 indicates that site water chemistry decreased Cu toxicity relative to standard laboratory dilution waters (i.e., waters used to develop the hardness-based Cu criteria). The lowest WER values were computed using the SMAV as the WER denominator, because the dissolved Cu EC50 values in the hardness-matched laboratory water were mostly less than the SMAV (the range of WER values using the hardness-matched laboratory water EC50 value as the WER denominator was 1.48–24.8; Supplemental Data, Table S4).

Because of the range of site water chemistries tested and because of the known influence of DOC and inorganic parameters (major cations, alkalinity) on aqueous Cu bioavailability [5,9], the wide variability in measured WER values was not surprising. However, the variability in WER values presents a challenge to implement site-specific criteria, especially in arid landscapes that contain ephemeral drainages not influenced by point-source discharges of Cu. For this scenario, a final site WER could theoretically be computed as the geometric mean of the measured WER values. For example, using the hardness-matched laboratory EC50s as the WER denominator, the geometric mean WER = 7.35, whereas using the SMAV as the WER denominator, the geometric mean WER = 5.00. However, it is clear that application of geometric mean WERs to this site would result in considerable uncertainty about the level of protection of derived site-specific criteria, depending on the water chemistry of a sample to which the WER is applied. In agreement with USEPA recommendations concerning WERs determined for sites not influenced by point sources of metal

Table 1. Chemistry of site waters in which *Daphnia magna* toxicity tests were conducted, and corresponding 48-h dissolved Cu median effect concentrations (EC50s) and water effect ratio (WER) values^a

| Site ^b | pH | | Hardness (mg/L as CaCO ₃) | Alkalinity (mg/L as CaCO ₃) | DOC (mg C/L) | Dissolved Cu (μg/L) | Dissolved Cu EC50 (μg/L) ^c | Dissolved Cu WER ^d |
|-------------------|------------|--------------|--|--|-----------------|------------------------|--|----------------------------------|
| | Test start | Test average | | | | | | |
| 1-1 | 8.00 | 8.19 | 90 | 74 | 10.7 | 5.9 | 116.3 | 6.651 |
| 1-2 | 7.47 | 7.88 | 84 | 60 | 7.8 | 6.5 | 87.39 | 5.334 |
| 1-5 | 7.54 | 7.66 | 62 | 28 | 3.5 | 32.3 | <32.3 ^e | NA |
| 1-6 | 7.57 | 7.88 | 54 | 42 | 12.5 | 57.4 | 155.7 | 14.41 |
| 1-7 | 7.93 | 8.06 | 106 | 66 | 7.8 | 43 | 96.23 | 4.717 |
| 1-9 | 8.04 | 8.29 | 88 | 90 | 2.5 | 7.1 | 37.78 | 2.207 |
| 1-10 | 8.31 | 8.60 | 262 | 250 | 4.7 | 5.4 | 134.2 | 2.804 |
| 1-11 | 8.22 | 8.48 | 154 | 170 | 15.7 | 4.3 | 172.8 | 5.956 |
| 1-12 | 9.35 | 8.69 | 76 | 27 | 1.2 | 2.1 | 14.74 | 0.989 |
| 1-RCS1 | 8.67 | 8.44 | 48 | 32 | 3.2 | 5 | 31.65 | 3.273 |
| 1-D1-2 | 8.06 | 8.19 | 54 | 76 | 10.0 | 32.3 | 141.6 | 13.10 |
| 1-D2-1 | 8.16 | 8.02 | 42 | 28 | 5.8 | 32.8 | 68.45 | 8.027 |
| 2-1 | 8.19 | 8.27 | 104 | 96 | 11.0 | 3.4 | 81.06 | 4.046 |
| 2-6 | 7.14 | 7.60 | 50 | 40 | 11.4 | 30.2 | 61.82 | 6.151 |
| 2-9 | 8.44 | 8.49 | 82 | 102 | 12.3 | 13.7 | >184.7 ^f | 11.53 |
| 2-11 | 7.99 | 8.24 | 102 | 106 | 12.3 | 7.9 | 135.5 | 6.889 |
| 2-12 | 7.40 | 7.70 | 80 | 34 | 3.1 | 3.6 | 35.23 | 2.251 |
| 2-D1-2 | 7.82 | 8.03 | 60 | 64 | 10.5 | 17.9 | 68.31 | 5.724 |

^aComplete water chemistry for each sample is listed in Supplemental Data, Table S2.

^bA "1-" prefix signifies Round 1 samples collected in August 2011; a "2-" prefix signifies Round 2 samples collected in September 2011.

^cDissolved Cu EC50 at tested hardness before normalization to a hardness of 100 mg/L as CaCO₃ for calculation of WER.

^dAll WERs were calculated using the *D. magna* species mean acute value of 19.31 μg/L dissolved Cu from the US Environmental Protection Agency [3] as the WER denominator, with the dissolved Cu EC50 normalized to a hardness of 100 mg/L as CaCO₃ in the numerator.

^eEC50 could not be calculated because >50% mortality occurred in unspiked site water.

^fEC50 is reported as greater than the highest tested Cu concentration because mortality was <50% in that treatment.

DOC = dissolved organic carbon; NA = not applicable because EC50 could not be calculated.

contamination [2], subsequent analyses were performed to determine whether WER variability could be attributed to the variability of measured water chemistry parameters.

Site water chemistry

Water chemistry parameters varied considerably in the tested site waters, particularly DOC, alkalinity, and major cations (Table 1)—parameters that previously have been demonstrated to modify Cu toxicity [9]. Concentrations of DOC differed among site water samples by more than 1 order of magnitude (1.2–15.7 mg/L), and 9 of the 17 samples contained DOC concentrations greater than or equal to 10 mg/L. Water hardness ranged from soft (42 mg/L as CaCO₃) to hard (262 mg/L as CaCO₃), with a >9-fold range in alkalinity concentrations (27–250 mg/L as CaCO₃). Although hardness and alkalinity concentrations in site samples were moderately correlated ($r=0.82$; Supplemental Data, Table S5), the hardness-to-alkalinity ratio ranged from 0.71 to 2.8 (Supplemental Data, Table S2). In most natural waters, alkalinity and hardness covary, with alkalinity generally equal to or slightly less than corresponding hardness [9]. Total suspended solids (TSS) were low (<13 mg/L, and mostly <5 mg/L), probably because all samples were collected from isolated pools without measurable flow.

Copper toxicity in site water

Similar to the range in WER values, we observed more than a 12-fold range among *D. magna* dissolved Cu EC50 values (14.7 μg/L to >184.7 μg/L). Hardness concentrations in these lowest and highest EC50 samples differed by only 6 mg/L as CaCO₃ (Table 1), and the overall correlation between hardness and toxicity in site samples was low ($R^2=0.102$, $p=0.211$; Table 2). This outcome suggests that Cu toxicity in the site

waters was controlled more by other water chemistry parameters, and that hardness alone was a poor predictor of Cu toxicity.

Based on the univariate regression analyses (Table 2), the best predictor of Cu toxicity in site waters was DOC ($R^2=0.751$; $p<0.001$). This result agrees with numerous other studies that evaluated the effects of multiple water chemistry parameters on Cu toxicity [10–12] and supports the contention that DOC should be incorporated in the derivation of water quality criteria [9]. Inorganic parameters determined to be significant predictors of Cu toxicity included (in sequence of decreasing level of statistical significance) hardness/alkalinity ratio ($R^2=0.539$; $p<0.001$), alkalinity ($R^2=0.428$; $p=0.004$), K ($R^2=0.322$; $p=0.018$), and total dissolved solids ($R^2=0.245$; $p=0.043$). With the exception of hardness/alkalinity, correlation coefficients from regressions of water chemistry parameters and EC50 values were positive, indicating that Cu toxicity decreased as concentrations of DOC, alkalinity, K, and total dissolved solids increased. This trend is consistent with results from other studies [9] and is a manifestation of the protective effects of these parameters on Cu bioavailability and toxicity. Mechanistically, DOC and alkalinity (i.e., predominantly HCO₃⁻ and CO₃²⁻ ions in most fresh waters) can form complexes with Cu, thereby decreasing the available fraction of Cu for biotic uptake. In contrast, cations such as K⁺ (and others such as Ca²⁺, Mg²⁺, and Na⁺) compete with Cu for binding sites on the biotic ligand [13], thus explaining the positive relationships observed between these cations and measured EC50 values. Presumably, the positive relationship between total dissolved solids and EC50 values is also at least partly reflective of this relationship because total dissolved solids, although not ion-specific, is the sum of the concentrations of dissolved inorganic and organic constituents. Therefore, the observed protective effect of total dissolved solids on Cu toxicity might reflect a combination of competition-based

Table 2. Results of univariate-regression analysis between *Daphnia magna* 48-h dissolved Cu median effect concentrations (EC50s) and measured water chemistry parameters in site-water toxicity tests

| Independent variable (x) | Regression equation | R ² | p |
|---|---|----------------|--------|
| pH | EC50 = 10 ^{3.394 - 0.186 × x} | 0.099 | 0.220 |
| Alkalinity (mg/L as CaCO ₃) | EC50 = 10 ^{0.571 + 0.730 × log [x]} | 0.428 | 0.004 |
| Hardness (mg/L as CaCO ₃) | EC50 = 10 ^{0.965 + 0.489 × log [x]} | 0.102 | 0.211 |
| Hardness/alkalinity | EC50 = 10 ^{2.026 - 1.428 × log [x]} | 0.539 | <0.001 |
| DOC (mg C/L) | EC50 = 10 ^{1.183 + 0.848 × log [x]} | 0.751 | <0.001 |
| TDS (mg/L) | EC50 = 10 ^{-0.591 + 1.108 × log [x]} | 0.245 | 0.043 |
| Ca (mg/L) | EC50 = 10 ^{1.111 + 0.617 × log [x]} | 0.159 | 0.112 |
| Mg (mg/L) | EC50 = 10 ^{1.495 + 0.450 × log [x]} | 0.117 | 0.179 |
| K (mg/L) | EC50 = 10 ^{1.298 + 1.085 × log [x]} | 0.322 | 0.018 |
| Na (mg/L) | EC50 = 10 ^{1.312 + 0.555 × log [x]} | 0.154 | 0.120 |
| SO ₄ (mg/L) | EC50 = 10 ^{2.583 + 0.467 × log [x]} | 0.179 | 0.091 |
| Fe (mg/L) | EC50 = 10 ^{1.520 + 0.292 × log [x]} | 0.153 | 0.120 |
| Al (mg/L) | EC50 = 10 ^{1.765 + 0.194 × log [x]} | 0.126 | 0.161 |

DOC = dissolved organic carbon; TDS = total dissolved solids.

mechanisms from cations and of complexation mechanisms from DOC and alkalinity.

Although hardness and alkalinity were moderately correlated with each other, only alkalinity was significantly correlated with Cu EC50s. Therefore, alkalinity is a better predictor of Cu toxicity in these site waters than is hardness. Copper toxicity increased (i.e., lower EC50 values) when alkalinity was proportionally lower than hardness, as shown by the negative relationship between EC50 values and the hardness/alkalinity ratio. Although pH commonly modifies Cu bioavailability and toxicity [9,11], pH was not significantly correlated with Cu toxicity in the present study. This might be the result of the relatively narrow range of circumneutral to alkaline waters tested (average pH from all site waters ranged from 7.6 to 8.69), compared with other studies that identified significant pH-related effects over a wider range that included slightly acidic waters (i.e., pH < 7 [11,14,15]). In fact, pH should have little direct effect on Cu toxicity at pH values above approximately 6.5 because hydrogen ions do not effectively compete for binding to biotic ligands until the pH is below approximately 6.5. However, pH can have an important indirect effect on Cu bioavailability by changing the HCO₃⁻/CO₃²⁻ ratio in the exposure water, thus leading to higher concentrations of CO₃²⁻ (which has a higher affinity for Cu than bicarbonate [9]) at higher pH values.

In multiple linear regressions, the combination of DOC ($p < 0.001$) and alkalinity ($p = 0.007$) was chosen as the best model, explaining 85% of the variability in observed Cu toxicity (Table 3). Models developed using a combination of DOC, hardness/alkalinity, and total dissolved solids or a combination of DOC, alkalinity, and K⁺ marginally improved the fit (based on the adjusted R² value), but the extra parameters were not statistically significant ($p = 0.127$ for hardness/alkalinity, and $p = 0.181$ for K; Table 3). Application of the hardness/alkalinity value as a predictor of Cu toxicity is also of potential concern because it does not account for absolute concentrations of alkalinity (i.e., a similar hardness/alkalinity ratio is possible at different alkalinity concentrations). In addition, because alkalinity was significantly correlated to K⁺ ($p = 0.03$, Supplemental Data, Table S5), adding K⁺ to the regression model might be duplicative and might result in unstable model predictions because of colinearity between alkalinity and K⁺.

Predicted EC50 values from the DOC-and-alkalinity model were strongly correlated to and generally within a factor of 1.6 of the observed EC50 values ($r = 0.92$; Figure 1). No bias was apparent between model-predicted and observed EC50 values

(i.e., no systematic over- or underprediction of toxicity), and the deviations in model predictions were not related to water chemistry variability (assessed by comparing the predicted EC50/observed EC50 ratio across water chemistry ranges; Supplemental Data, Figure S2). The strong linear relationship and lack of bias in model predictions suggest that Cu toxicity in these site waters can be accurately predicted by a combination of the DOC and alkalinity concentrations, consistent with the current mechanistic understanding of Cu toxicity to aquatic organisms.

Other researchers have developed similar regression-based predictive models to describe the effects of multiple water chemistry parameters on Cu toxicity [10,11,16] and Pb toxicity [17]. In the predictive models developed previously for Cu, DOC was included as the most significant predictor of Cu toxicity, which was also the case in the present study. Through stepwise multiple regression of dissolved Cu 48-h EC50s for larval fathead minnows (*Pimephales promelas*) on water chemistry parameters, Van Genderen et al. [16] also identified DOC and alkalinity as significant variables for predicting Cu toxicity in ambient surface waters. De Schampelaere and Janssen [11] similarly developed a regression model to predict chronic toxicity of Cu to *D. magna* based on DOC and pH, although they tested a much wider pH range than in the present study.

Table 3. Results of multiple linear regressions between *Daphnia magna* 48-h dissolved Cu median effect concentrations (EC50s) and measured water chemistry parameters in site-water toxicity tests ($n = 17$)

| Independent variables (p value in parentheses) ^a | R ² | Adjusted R ² | Regression p |
|--|----------------|-------------------------|--------------|
| DOC (<0.001); H/A (0.127); TDS (0.006) | 0.868 | 0.838 | <0.001 |
| DOC (0.002); H/A (0.179); TDS (0.023); pH (0.736) | 0.869 | 0.826 | <0.001 |
| DOC (<0.001); alkalinity (0.199); TDS (0.448) | 0.861 | 0.829 | <0.001 |
| DOC (<0.001); alkalinity (0.007) | 0.854 | 0.833 | <0.001 |
| DOC (<0.001); alkalinity (0.014); pH (0.78) | 0.855 | 0.822 | <0.001 |
| DOC (<0.001); alkalinity (0.037); K ⁺ (0.181) | 0.874 | 0.844 | <0.001 |

^aExcept for pH, all variables were log₁₀-transformed for regression analysis. DOC = dissolved organic carbon; H/A = hardness/alkalinity ratio; TDS = total dissolved solids.

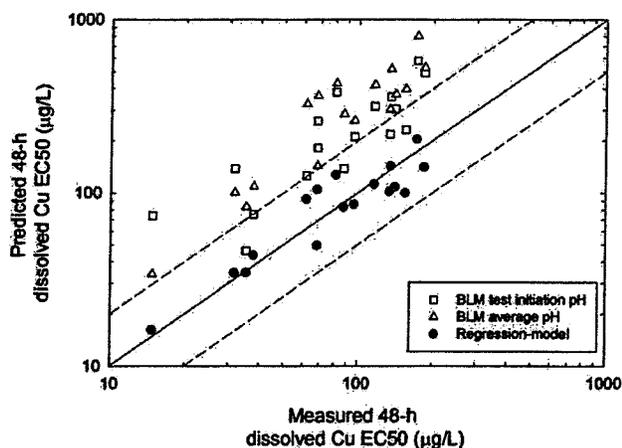


Figure 1. Observed, regression model-predicted, and biotic ligand model (BLM)-predicted 48-h dissolved Cu median effect concentrations (EC50s) in *Daphnia magna* toxicity tests conducted in site waters. Regression model included dissolved organic carbon and alkalinity as predictor variables ($R^2=0.854$). Biotic ligand model predictions were based on default model parameters and using pH measured at test initiation (0 h exposure; $R^2=0.686$) or the average pH from 0- and 24-h exposure ($R^2=0.855$). Solid line represents a perfect (1:1) fit; dashed lines are ± 2 -fold of the perfect fit.

Model implementation

The primary source of variation in WER values is the site water toxicity endpoint (i.e., the EC50 value), which is an indicator of the toxicity-modifying properties of site water and, thus, the subsequent relationship to the current hardness-based ambient water quality criteria that are still used by individual states in the United States. The regression model developed in the present study provides a site-specific equation to accurately predict acute Cu toxicity in site waters and, therefore, an option to accurately predict WER values at a much wider variety of locations and times than would be economically reasonable using toxicity tests. Because the *D. magna* SMAV was selected as the preferred WER denominator in the present study, it can be applied uniformly to all regression model-predicted site water Cu EC50 values to calculate a WER value. This approach also eliminates the laboratory water EC50 values as a source of WER variability (e.g., laboratory water EC50 values of 4.0 $\mu\text{g Cu/L}$ and 6.0 $\mu\text{g Cu/L}$ at hardness concentrations of 42 mg/L and 46 mg/L as CaCO_3 that were determined during WER-testing Round 1 in Supplemental Data, Table S4), as suggested by others to improve interpretation of WER values [18]. A predicted WER value can thus be calculated by normalizing the regression-predicted EC50 value and the *D. magna* SMAV to the same hardness:

$$\text{WER} = \frac{\text{predicted site-water EC50}_{\text{hardness-normalized}}}{D. magna SMAV_{\text{hardness-normalized}}} \quad (2)$$

An advantage of applying the regression model approach to the WER procedure is that it provides an option to account for water chemistry variability when site-specific criteria are being developed. Similar to the current hardness-based ambient water quality criteria that are still used by individual states in the United States, whereby a Cu criterion is calculated based on the water hardness of the sample, a regression-based WER value can be calculated for a sample based on water chemistry values. However, the current regression model should be applied only to

the surface waters from which it was developed (i.e., the present study area), because the model is calibrated to the specific chemistries of the tested waters, which includes dissolved organic matter containing site-specific types and percentages of active humic and fulvic acids. Care should also be taken when applying the model to site-specific surface waters that have DOC and alkalinity concentrations outside the range used to develop the model. For this potential scenario, the authors recommend that DOC and alkalinity be capped at the upper concentrations that were used to develop the model (i.e., a DOC concentration of 15.7 mg/L and an alkalinity concentration of 250 mg/L as CaCO_3). In contrast, the model can be applied to DOC and alkalinity concentrations lower than the range used to develop the model, to ensure that the predicted EC50 and WER values are sufficiently protective at low DOC and alkalinity concentrations.

BLM performance in site waters

The BLM-predicted 48-h dissolved Cu EC50 values in site waters always exceeded the corresponding measured EC50 values and in most cases were more than 2-fold greater than observed values (Figure 1). This result implies that the BLM underpredicts Cu toxicity in these site waters. Because Kolts et al. [19] concluded that most of the exposure that determines acute Cu toxicity to cladocerans occurs during the first few hours, we compared the performance of the BLM using pH measured at test initiation (0 h exposure) and the average of the 0-h and 24-h pH values. Using the average pH produced BLM-predicted EC50 values that correlated better with observed values ($r=0.92$) than those using the initial pH values ($r=0.83$), but they still were always at least 2-fold greater than observed values. The systematic error in BLM predictions (i.e., constant underprediction of toxicity) might suggest: (1) a sensitivity difference between tested organisms and those used to develop the BLM, M and/or (2) a difference in the quality of DOC in site waters compared with those used to develop the BLM (i.e., different Cu-binding affinity or different binding-site density).

To explain the discrepancy between BLM-predicted and measured toxicity, we also evaluated the performance of the default BLM in the concurrent laboratory water toxicity tests. Most BLM-predicted EC50 values for laboratory waters were within a factor of 2 of observed values; however, a bias was still evident because predicted values consistently exceeded observed values, although the magnitude of differences for laboratory waters generally was less than for the site waters (Figure 2A). One option to optimize the BLM performance is to adjust the default sensitivity parameter (i.e., the median lethal accumulation [LA50]), because the *D. magna* used in these WER tests might have been slightly more sensitive than the composite sensitivity of the *D. magna* that were used to parameterize the BLM. This is a reasonable option in the present study because the BLM tended to overpredict the EC50 values in laboratory waters, which represent the type of water chemistries used to develop the BLM (i.e., laboratory type waters with approximately equal hardness and alkalinity, low DOC, and circumneutral pH).

To optimize the *D. magna* LA50 for the current laboratory water dataset, the default LA50 value was adjusted downward from 0.119 nmol to 0.057 nmol Cu/g wet weight so the geometric mean of the BLM-predicted EC50/observed EC50 ratio equaled 1.0 among the 11 laboratory waters, based on the approach described in Meyer and Adams [20]. This adjustment provided a reasonable fit between predicted and observed values for the laboratory water tests (Figure 2B) and was assumed to

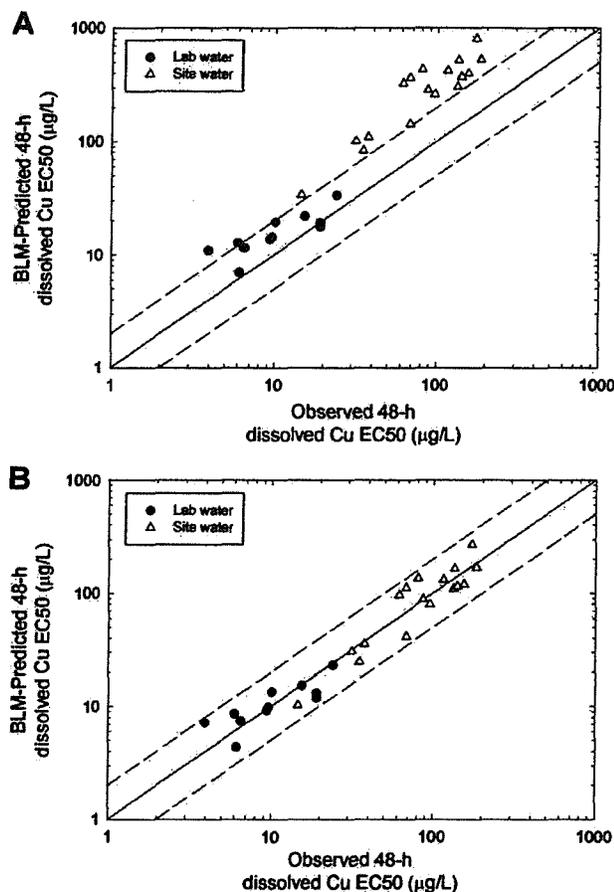


Figure 2. Biotic ligand model (BLM) predictions of *Daphnia magna* 48-h dissolved Cu median effect concentrations (EC50s) in laboratory and site waters, based on (A) the default BLM parameterization and (B) an optimized BLM. The BLM was optimized by first adjusting the sensitivity parameter (i.e., the median lethal accumulation of Cu on the biotic ligand) to improve the fit between BLM-predicted and observed laboratory water EC50 values (adjusted LA50 = 0.057 nmol Cu/g wet wt). Then the reparameterized BLM was applied to measured site water chemistries after decreasing measured site water DOC concentrations by 57%. Solid line represents a perfect (1:1) fit; dashed lines are ± 2 -fold of the perfect fit.

calibrate the BLM to the sensitivity of the organisms used in the WER toxicity tests. As an indication of the sensitivity of the LA50 to the assumed DOC concentration in the laboratory waters, the LA50 increased to 0.130 nmol Cu/g wet weight when the lower-bound assumed DOC concentration was 0.3 mg C/L and decreased to 0.0333 nmol Cu/g wet weight when the upper-bound assumed DOC concentration was 0.7 mg C/L.

However, that organism-sensitivity adjustment did not completely eliminate the bias in BLM-predicted EC50 values in the site waters. One possible explanation for this difference is the quality of DOC in site waters relative to the DOC used to calibrate the default BLM. Because the BLM overpredicted the EC50 values in site waters (even after adjusting the LA50 value to optimize the laboratory water predictions), a way to decrease the predicted EC50 values is to proportionally decrease each sample's DOC concentration that is inputted into the BLM. In effect, this would increase the percentage of free Cu available to bind to the biotic ligand site(s), thereby decreasing the EC50 values. This approach has been applied previously for *D. magna* toxicity tests [21–23]. A similar approach was applied in the present study to determine the percentage of the

measured DOC concentration at which the geometric mean of the BLM-predicted EC50/observed EC50 ratio of the site waters equaled 1.0.

After adjusting the LA50 downward to 0.057 nmol Cu/g wet weight for an assumed 0.5 mg DOC/L in the laboratory waters and applying that LA50 to the site water toxicity results, decreasing the measured DOC concentrations in the site waters by 57% (i.e., assuming only 43% of the DOC interacted with Cu) provided the optimized fit ($r=0.97$) of the BLM-predicted EC50 values compared with measured values (Figure 2B). This is similar to the refined BLM model described by De Schampelaere et al. [21,22], in which 50% of the DOC was considered to be active fulvic acid and thus the fraction of DOC that binds with Cu. As an indication of the sensitivity of that site water DOC-adjustment factor to the assumed DOC concentration in the laboratory waters, decreasing the measured DOC concentrations in the site waters by 71% (i.e., assuming only 29% of the DOC interacted with Cu) provided the optimized fit ($r=0.97$) of the BLM-predicted EC50 values compared with measured values when the DOC concentration in the laboratory waters was 0.3 mg C/L; decreasing the measured DOC concentrations in the site waters by 42% (i.e., assuming only 58% of the DOC interacted with Cu) provided the optimized fit ($r=0.97$) of the BLM-predicted EC50 values compared with measured values when the DOC concentration in the laboratory waters was 0.7 mg C/L. Therefore, when one is trying to determine how to parameterize the DOC in site waters for input into the BLM, it is important to determine the sensitivity (i.e., the LA50) of the toxicity-test organisms in a laboratory water that is well characterized (especially having a detectable DOC concentration) before adjusting the DOC inputs to the BLM.

CONCLUSIONS

The acute toxicity of Cu varied across site-specific water chemistries in a manner consistent with the current mechanistic understanding of Cu toxicity. Dissolved organic carbon concentration was the most significant predictor of Cu toxicity in the present study, but other water chemistry parameters were also significantly correlated with Cu toxicity, including the hardness/alkalinity ratio, alkalinity, total dissolved solids, and K^+ concentration. A multiple-regression model developed from a combination of measured concentrations of DOC and alkalinity explained 85% of the observed toxicity variability, thereby providing a strong predictive tool that can be applied to the WER procedure framework to address water chemistry and toxicity variability.

Although the multiple regression derived for this site-specific scenario predicts *D. magna* EC50 values more accurately than the BLM-predicted EC50 values, the default BLM predictions were not excessively biased and were strongly correlated to observed toxicity values. After accounting for an approximately 2-fold adjustment of the LA50 needed to compensate for the apparent difference in sensitivity between the *D. magna* used in these toxicity tests and the composite *D. magna* used to calibrate the default Cu BLM, another factor of approximately 2 was needed to adjust the DOC concentrations of the site water. Therefore, the default Cu BLM predicted *D. magna* EC50 values reasonably well in the ambient site waters, but the site-specific regression model predicted the EC50 values considerably better than did the default BLM. However, because safety margins are incorporated into the derivation of criteria concentrations for metals (i.e., criteria concentrations are derived in an environmentally conservative manner), these results do not necessarily

mean that BLM-based Cu criteria concentrations will not still be protective of aquatic life.

SUPPLEMENTAL DATA

Tables S1–S5.

Figures S1–S3. (265 KB PDF).

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