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WATER QUALITY CONTROL COMMISSION

STATE OF NEW MEXICO
BEFORE THE WATER QUALITY CONTROL COMMISSION

IN THE MATTER OF THE TRIENNIAL REVIEW OF STANDARDS FOR INTERSTATE AND INTRASTATE SURFACE WATERS, 20.6.4 NMAC **WQCC No. 14-05(R)**

REBUTTAL TESTIMONY OF ROBERT W. GENSEMER, Ph.D.
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I. INTRODUCTION

I have prepared the following rebuttal testimony on behalf of Chevron Mining Inc. (CMI) in response to the direct testimony of Deke Gundersen, Ph.D. submitted on behalf of Amigos Bravos ("Gundersen Direct Testimony"). *See* Amigos Bravos' Notice of Intent to Submit Technical Testimony (filed December 12, 2014). Amigos Bravos proposes to repeal the current hardness-based criteria for aluminum (Al) that were adopted by the New Mexico Water Quality Control Commission ("WQCC") in the 2009 Triennial Review of Surface Water Quality Standards ("2009 Triennial Review"), and subsequently approved by the U.S. Environmental Protection Agency ("USEPA"), and revert back to the over 25 year old aquatic life criteria that were in place prior to the 2009 Triennial Review.

The Gundersen Direct Testimony expresses concerns over the technical basis of the hardness-based aluminum criteria that were adopted during the 2009 Triennial Review, ultimately concluding that these criteria would not be protective of aquatic life in New Mexico waters. As I presented in my direct testimony ("Gensemer Direct Testimony"), filed December 12, 2014, these hardness-based criteria were derived according to USEPA guidance for development of national ambient water quality criteria (AWQC; USEPA 1985) and were thoroughly reviewed by the New Mexico Environment Department (NMED) and USEPA, leading ultimately to formal approval by the WQCC (*See* Order and Statement of Reasons; WQCC 2010b, paragraph 511) and USEPA in its final decision letter and Record of Decision (ROD) Addendum (USEPA 2012). As stated in the transmittal letter to the ROD Addendum:

> *Based on an extensive review of the supporting documentation, we are approving the application of the hardness-dependent equation for aluminum to those waters of the State at a pH of 6.5 to 9.0 because it will yield criteria that are protective of applicable uses in waters within that pH range.*

It is important to note that Amigos Bravos participated in the 2009 Triennial Review and did not challenge or express technical concerns with these criteria at any time during the hearing process, even though many of the concerns raised in the Gundersen Direct Testimony could have been raised at the time.

In this Rebuttal Testimony, I summarize, and respond to, many of the key technical concerns raised in the Gundersen Direct Testimony. Much of these concerns related to protectiveness of the existing hardness-based aluminum criteria at alkaline pH owing to the relative lack of aquatic toxicity studies conducted at alkaline pH at the time of the 2009 Triennial Review as summarized in the 2009 pre-filed direct testimony reports from CMI and Los Alamos National Security LLC ("LANS"); *See* Exhibits 2 and 4 from Gensemer Direct Testimony. It is my opinion, based on my review of technical concerns raised in the Gundersen Direct Testimony, that the existing hardness-based aluminum criteria (20.6.5.900 NMAC) are adequately protective of aquatic life in New Mexico, even under relatively alkaline pH (i.e., from 7.5 – 9.0). Therefore, it is neither necessary nor scientifically defensible for the WQCC to approve Amigos Bravos' proposal to revert to the vastly outdated and scientifically unsupportable pre-2009 criteria.

II. REBUTTAL TO SPECIFIC COMMENTS FROM AMIGOS BRAVOS DIRECT TESTIMONY

I provide the following responses to key technical comments from the Gundersen Direct Testimony with respect to the hardness-based aluminum criteria currently in place in New Mexico. My rebuttal testimony does not provide an exhaustive response to each individual comment, but rather, responses are provided to comments that I consider key to assisting the WQCC in evaluating Amigos Bravos' proposal to revert back to the outdated criteria in place prior to 2009.

- **Gundersen Comment**: *There is no evidence that GEI provided "sound scientific evidence" that the EPA recommended aluminum criteria were "substantially overprotective" based on my review of reports describing the procedure for calculating the hardness based aluminum criteria in New Mexico… (See* Gundersen Direct Testimony at 3*).*

Response: As stated above, sound scientific evidence was indeed provided in the pre-filed direct testimony during 2009 Triennial Review (GEI 2009, LANS 2009a), with additional information provided in pre-filed rebuttal testimony (CMI 2009; LANS 2009b). This information was subject to technical review and approval by both the WQCC and USEPA (*See* Gensemer Direct Testimony at 7-8). This evidence strongly supported the development of aluminum criteria to be derived on the basis of hardness, such that the previous criteria of 750 and 87 µg Al/L (acute and chronic criteria, respectively) were substantially overprotective at hardness values greater than those from the toxicity tests used to derive the chronic criterion value in particular (brook trout and striped bass). These brook trout and striped bass studies were conducted at very low hardness (12.3 – 14 mg/L as $CaCO_3$) and, in fact, the New Mexico hardness criteria equation would derive low criteria that are sufficiently protective of those values (*See* LANS 2009a at 8-9). Therefore, for waters with hardness substantially higher than 12-14 mg/L, the fixed criteria values of 750 and 87 µg Al/L would indeed be overprotective when considered against the USEPA-approved aluminum criteria equations (*See* 20.6.4.900 I(3) NMAC).

- **Gundersen Comment:** *Indeed, EPA region III rejected the proposal submitted by the West Virginia Department of Environmental Protection for hardness-based aluminum criteria (Developed by GEI, August 2011) due to concerns over lack of protection for* *local species (InsideEPA.com; Doc. ID: 2461044), and the current development of new National aluminum criteria.* (*See* Gundersen Direct Testimony at 4)

Response: It is incorrect that USEPA Region III rejected the West Virginia proposal for hardness-based criteria. While it is correct that USEPA Region III had concerns over the protection of mussels and indicated that USEPA was in the process of obtaining additional toxicity data, their response letter to the West Virginia Department of Environmental Protection (WVDEP) was not a rejection. The letter concluded: *Please note that our comments above are preliminary in nature and do not constitute a final decision by EPA under Clean Water Act § 303(c). Approval/disapproval decisions will be made by the Region following adoption of any new/revised standards by the state and submittal to EPA.* (*See* Gensemer Testimony Exhibit 8; USEPA 2014, Letter from E.S. MacKnight to S.G. Mandirola). Since WVDEP withdrew their proposal, no final action was taken by USEPA Region III on the proposal.

- **Gundersen Comment**: *EPA, in its revisions, is evaluating the use of a simplified aluminum Biotic Ligand Model (BLM) using four parameters (pH, dissolved organic carbon, hardness, and temperature), due to the complex nature between aluminum toxicity and water quality (Eignor 2014). In addition, there are recent studies (soon to be published) that will provide additional information on aluminum toxicity at the neutral and alkaline pH range. One of these studies looking at chronic aluminum exposures to a variety of species at pH 6.0 found that the zebrafish had an EC10 of 80 µg/L total aluminum (Stubblefield et al. 2012). This suggests that application of hardness-based aluminum criteria, such as New Mexico's current criteria, at least before these studies are published, is not practical or scientifically sound* (*See* Gundersen Direct Testimony at 4).

Response: I am aware of USEPA's plans for updating the national AWQC for aluminum, and their consideration for a BLM-based approach to incorporate the effects of pH, dissolved organic carbon, hardness, and temperature on aluminum toxicity in any updated national criteria. As stated in my direct testimony (*See* Gensemer Direct Testimony at 3), I have been part of the expert technical team supporting the European Aluminium Association to oversee the conduct of new chronic toxicity studies to support their participation in Europe's Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) program. All of the completed toxicity study reports have been shared with USEPA for their use in the national AWQC updates, as has been our plans for development of a BLM-based approach for these criteria. These data will also be submitted for publication in a peer-reviewed scientific journal this year.

The Stubblefield et al. (2012) presentation (*See* Gundersen Direct Testimony at 4), and for which I am the fourth author, reflects some of the results from the REACH studies. However, the studies in this presentation were all conducted at or near a pH of 6.0, and so these results are not valid for evaluating the protectiveness of the current New Mexico aluminum criteria since they only apply to waters from pH 6.5 – 9.0. As presented in my direct testimony (*See* Gensemer Direct Testimony at 9), New Mexico's hardness-based aluminum criteria were never intended to be applied to waters of pH outside this range, and were not approved by USEPA for waters of pH outside this range. Therefore, the results from the Stubblefield et al. (2012) should not be used to evaluate the appropriateness of the existing New Mexico hardness-based aluminum criteria.

- **Gundersen Comment**: *Why are the GEI Derived Colorado, West Virginia, and New Mexico Hardness-Based Aluminum Criteria Different?* (*See* Gundersen Direct Testimony at 4).

Response: For all three states, GEI originally proposed the same acute and chronic aluminum criteria equations as a function of hardness (GEI 2009, LANS 2009a, GEI 2010, GEI 2011):

$$\text{Acute Criterion} = e^{(1.3695[\ln(\text{hardness})]+1.8308)}$$

$$\text{Chronic Criterion} = e^{(1.3695[\ln(\text{hardness})]+0.9161)}$$

These equations represent the most appropriate and scientifically defensible criteria based on the database available at the time of the criteria proposals made in all three states. However, the chemical form of aluminum to be measured for compliance with the aluminum criteria in various states has varied in an attempt by each state to best reflect the toxic forms of aluminum to aquatic organisms.

In the case of both West Virginia and New Mexico, the existing aluminum standards in place prior to submitting our proposals were already expressed as a function of dissolved metal. During the 2009 New Mexico Triennial Review hearing, LANS originally proposed implementing criteria on the basis of dissolved aluminum (LANS 2009a); CMI proposed their criteria on the basis of "acid-soluble" aluminum (GEI 2009). Acid soluble represents the amount of metal that passes through a 0.45 µm filter after mild acidification, and so is less aggressive than a total recoverable assay. In fact, the 1988 USEPA AWQC for aluminum also suggests that criteria be expressed on the basis of acid-soluble metals to best reflect the forms of aluminum to which organisms are exposed in laboratory toxicity tests (*See* USEPA 1988 at 10-12).

However, New Mexico does not have a promulgated analytical method for acid soluble aluminum. Therefore, concerns were expressed during the 2009 Triennial hearing regarding the appropriateness of implementing these hardness-based criteria as a function of dissolved vs. total recoverable metal (for which promulgated methods exist). This was because while some insoluble amorphous aluminum hydroxides can cause toxicity and would be removed by filtration for a dissolved metal analysis, total recoverable metal assays in a field sample will also measure aluminum from mineral solids (e.g., clays) that are not available or toxic to aquatic organisms (*See* Hearing Officer's Report at 284-285; WQCC 2010a). In the case of laboratory toxicity tests, organisms are not exposed to mineral phases of aluminum, but rather dissolved or insoluble amorphous aluminum (e.g., $Al(OH)_3$) which are formed from "spiking" a toxicity test solution with a concentrated aluminum stock solution, usually prepared from an aluminum nitrate or sulfate salt. Therefore, field measurements of "dissolved" vs. "total recoverable" metal do not directly translate to the forms of aluminum that are created in laboratory test solutions. This presents an uncertainty as to whether dissolved or total recoverable metal measurements would be most appropriate for compliance with an aluminum water quality standard.

To resolve this uncertainty, discussions were held amongst CMI, LANS, and NMED technical staff during the 2009 Triennial Review to develop a method that would minimize both the potential for false negative results from using a dissolved measurement, as well as for false positive results from using a total recoverable measurement. As a result, the final aluminum standards in New Mexico were amended with the following condition that was acceptable to all parties: *The criteria are based on analysis of total recoverable aluminum in a sample that is filtered to minimize mineral* *phases as specified by the department* (*See* Hearing Officer's Report at 285; Order and Statement of Reasons at paragraph 516, WQCC 2010b; and 20.6.4.900 I(1 & 2) NMAC). In the case of West Virginia, GEI only prepared the initial proposal (GEI 2011) and did not participate in any of the hearings with WVDEP or USEPA Region III. Therefore, I do not know why the "Proposed West Virginia Standards" as presented in Table 1 of the Gundersen Direct Testimony presents slightly different equations that incorporate conversion factors.

In Colorado, GEI originally proposed the same hardness-based criteria equations as currently in place in New Mexico, also to be implemented on the basis of acid-soluble aluminum for which Colorado does have similar promulgated analytical method called "potentially-dissolved" (*See* GEI 2010 at 21-22). However, during the public comment portions of the Basic Standards Hearing (Colorado's equivalent to a Triennial Review), concerns from other stakeholders were expressed with respect to levels of protection for chronically-sensitive species based on studies that would not be deemed acceptable for use according to USEPA (1985). As a result, the final hardness-based criteria reflected a negotiated, rather than scientific, outcome that led to a different chronic equation compared with the existing New Mexico hardness-based criteria (*See* Colorado Water Quality Control Commission, Regulation 31, The Basic Standards and Methodologies for Surface Water at 56):

$$\text{Chronic Criterion} = e^{(1.3695[\ln(\text{hardness})]-0.1158)}$$

This equation resulted from setting the Final Chronic Value to the Species Mean Chronic Value for *Daphnia magna* of 189 µg/l, rather than the originally proposed Final Chronic Value of 530 µg/l (*See* USEPA 2011 Final Action letter at 15) calculated using an acute-to-chronic ratio (ACR; *See* GEI 2010). I still support the originally-proposed ACR-based chronic equation; I believe the resulting equation is still protective of acceptable chronic toxicity tests available at the time, and most consistent with USEPA guidance (USEPA 1985).

In summary, the differences between the various proposed and final hardness-based criteria for New Mexico, Colorado, and West Virginia are mostly a reflection of differences in the outcome of stakeholder deliberation and compromises reached during the public hearing process, rather than new and acceptable scientific information that would warrant changes to the existing, and USEPA-approved, New Mexico hardness-based criteria equations.

- **Gundersen Comment**: *Interestingly, the EPA-funded Arid West Water Quality Research Project (AWWQRP, May 2006) developed hardness-based aluminum equations for the region (which includes New Mexico) that are different from the New Mexico/Colorado equations, which included recreationally important species (rainbow trout).* (*See* Gundersen Direct Testimony at 5).

Response: I participated in development of the hardness-based aluminum criteria equations prepared for the AWWQRP (2006) report, and these are the earliest version of these hardness equations that Steve Canton (CMI expert witness for the 2009 Triennial Review) and I derived. Prior to submittal of our pre-filed direct testimony reports for the 2009 New Mexico Triennial (LANS 2009a, GEI 2009), we carefully re-evaluated the scientific basis of these criteria and consistency with USEPA guidance (USEPA 1985). This led to changes in which studies we considered acceptable, or not, for inclusion in development of the hardness equation specifically. The reasons for making these decisions are presented in full in our 2009 pre-filed direct testimony reports, and so do not rely upon—or necessarily need to agree with—equations prepared 3 years earlier.

Simply put, the analyses we conducted for the 2009 Triennial represent an update to the AWWQRP (2006) work that represents a more technically defensible set of aluminum criteria equations.

- **Gundersen Comment:** *GEI's derivation of New Mexico aluminum criteria equations does not include data from recreationally important species.* (*See* Gundersen Direct Testimony at 6).

Response: Calculation of the New Mexico aluminum criteria equations does, in fact, include data from recreationally important species such as rainbow trout, including acute toxicity tests conducted at several hardness values at pH 8.3 (Gundersen et al. 1994). Furthermore, all decisions with respect to exclusion of particular studies were subject to review by all parties to the 2009 Triennial Review (including Amigos Bravos), and was ultimately reviewed and approved by USEPA as summarized in the Gensemer Direct Testimony (at 7-8). Therefore, I continue to support these decisions; they ultimately led to development of hardness-based criteria that USEPA approved as being protective of aquatic life in New Mexico. Below I respond to two specific suggested inclusions presented in the Gundersen Direct Testimony, for which I conclude are not scientifically appropriate.

Thomsen et al. (1988). The results from this study were excluded from the 2009 criteria proposals because 1) the study duration was too long for an acute test, but too short for an acceptable chronic test with this species; 2) only calcium (Ca) concentrations were reported rather than hardness; and 3) potential confounding effects of low Ca concentrations on organism survival in the soft water treatments (*See* LANS 2009a at 5). Upon further review, I am most concerned that it is impossible to determine what exposure period was used in studies to derive the LC50 values of 3,800 and 71,000 µg

Al/L at 1 and 150 mg/L calcium. The methods section of the paper only mentions that these LC50 values were "…investigated **on** day 25 after hatching…" (*See* Thomsen et al. 1988 at 294, emphasis added). No other exposure duration details were provided in the paper; so, it is impossible to determine how long the organisms were actually exposed to aluminum, or indeed whether it could have been 48hrs as suggested in the Gundersen Direct Testimony.

Therefore, there is no valid basis for inclusion of Thomsen et al. 1988 study in the derivation of aquatic life criteria, even if all the information were known with respect to water hardness. The Gundersen Direct Testimony correctly points out that actual water hardness would have been higher than 1 or 150 mg/L (which were the values used in AWWQRP 2006 hardness slope calculations, but which would be incorrect) when expressed on the basis of calcium carbonate ($CaCO_3$), with or without estimates of likely magnesium (Mg) concentrations (although no information is presented in by the authors as to the type of incubation water used, so it would be impossible to estimate a Ca:Mg ratio). However, even if one were to assume that the hardness values from study would have been 2.5 and 375 mg/L as $CaCO_3$ (by simply converting Ca concentration to equivalent units expressed as $CaCO_3$), both the acute and chronic criteria equations would be more than adequately protective of these very high LC50 values from Thomsen et al. 1988 (Figure 1):

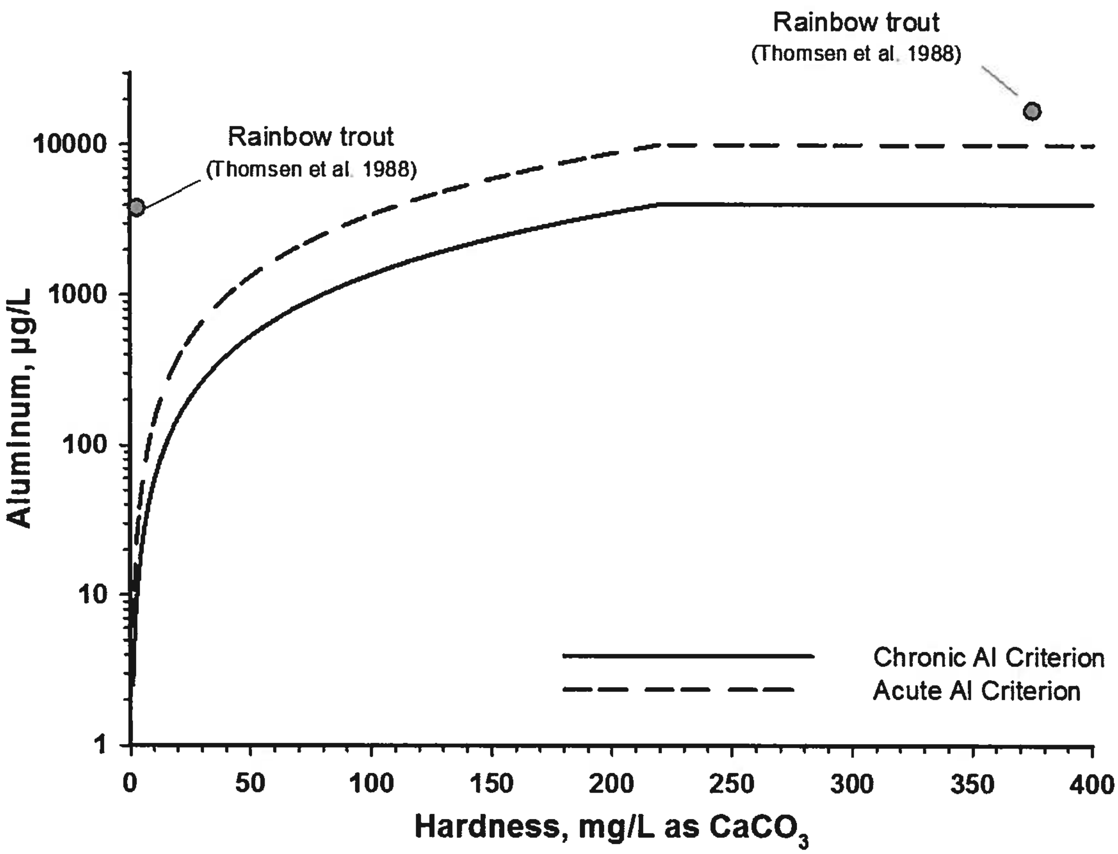

Figure 1: Aluminum LC50 values for rainbow trout from tests of unspecified duration from Thomsen et al. (1988) in hardness units of calcium expressed as mg/L calcium carbonate (magnesium concentrations were not reported nor could be estimated). These are plotted in comparison to existing acute and chronic aluminum criteria equations as per 20.6.4.900 NMAC.

Gundersen et al. (1994). These data were excluded from derivation of the existing hardness slope of 1.3695 because the range of definitive LC50 values (i.e., those with unbounded "greater than" or "less than" LC50 values which cannot be used for hardness slope derivation according to USEPA 1985) was not as high as that specified in USEPA guidance; *See* LANS 2009a at 7. If, instead, the definitive LC50 values from Gundersen et al. (1994) from the three lowest hardness levels were included in hardness slope calculation as suggested by Amigos Bravos (*See* Gundersen Direct Testimony at 6), they would only decrease the pooled harness slope by a minor degree (Table 1) to 1.2189, as compared to the existing hardness slope of 1.3695. Therefore, the exclusion of these values from the hardness slope calculation would not change the hardness slope enough to warrant abandoning the current criteria and reverting to a non-hardness-based aluminum criteria, as suggested by Amigos Bravos.

Table 1: Recalculated pooled species mean acute hardness slope for aluminum by adding the LC50 values from the three lowest hardness treatments (based on "total" aluminum values presented in Table 5 of Gundersen et al. 1994).

Species	N	Species Mean Acute Slope	R^2
Ceriodaphnia dubia	7	0.8699	0.73
Daphnia magna	2	1.4439	--
Pimephales promelas	5	1.5298	0.9
*Oncorhynchus mykiss**	3	0.1822	0.90
	Pooled Hardness Slope =	**1.2189**	**0.79**

*Gundersen et al. 1994

- **Gundersen Comment**: *Some of the studies used by GEI to derive values in the hardness-based aluminum equations should not be used.* (See Gundersen Direct Testimony at 7)

Response: Similar to the previous comment, all decisions with respect to inclusion of particular studies were subject to review and comment by all parties to the 2009 Triennial Review (including Amigos Bravos), and were ultimately reviewed and approved by USEPA, as summarized in the Gensemer Direct Testimony. Therefore, I continue to support these decisions. They ultimately led to development of hardness-based criteria that USEPA could approve as being protective of aquatic life in New Mexico. Below I respond to specific suggested exclusions suggested in the Gundersen Direct Testimony for which I conclude are not necessary or scientifically appropriate.

Khangarot (1991). According to the results of this study, the worm *Tubifex tubifex* represented the 4^{th} most acutely sensitive genus (genus mean acute value of 5,698 μg Al/L) after normalizing to a hardness of 50 mg/L. While it is true that aluminum exposure concentrations were not measured in this study, it was decided that these data were still acceptable for inclusion to provide an additional genus mean acute value to represent as many different types of aquatic taxa as possible for which a reported hardness value existed. The Gundersen Direct Testimony is correct in that the reported hardness value is not consistent with the hardness one would calculate from the reported Ca and Mg concentrations. Concern was also expressed that the aluminum ammonium sulfate salt used in the toxicity tests might have contributed ammonium to the exposure system (*See* Gundersen Direct Testimony at 7), but no evidence was presented that the amounts may have actually contributed to toxicity.

Given these uncertainties in the Khangarot (1991) study, we evaluated the influence of omitting this study from the overall criteria calculation in Table 2 below. Because the *Tubifex* Genus Mean Acute Value (5,698 μg Al/L) was similar to the next most sensitive genus, fathead minnow (*Pimephales promelas*, Genus Mean Acute Value of 5,869 μg Al/L), removing this study would only have a minor impact on the resulting Final Acute value at a hardness of 50 mg/L (Table 2). This Final Acute Value would be 2,578 μg Al/L as compared to the Final Acute Value used in the current New Mexico hardness-based criteria of 2,648 μg Al/L (*See* LANS 2009a, at Table 3), which only represents a decrease of 2.6%. Therefore, the inclusion of this study has little impact on the resulting aluminum criteria calculations, so there is little practical need to exclude this study or otherwise revise the existing aluminum criteria on the basis of uncertainties in the Khangarot (1991) study.

Table 2: Ranked Genus Mean Acute Values from LANS (2009a) Table 3, after removal of *T. tubifex*.

Rank	Genus Mean Acute Value (µg Al/L)	Species	Species Mean Acute Value (µg Al/L)	Species Mean Acute Chronic Ratio
16	>338,321	*Tanytarsus dissimilis* (midge)	>338,321	-
15	>53,794	*Lepomis cyanellus* (green sunfish)	>53,794	-
14	>53,578	*Perca flavescens* (yellow perch)	>53,578	-
13	>51,534	*Ictalurus punctatus* (channel catfish)	>51,534	-
12	32,922	*Physa* sp. (snail)	32,922	-
11	>24,315	*Acroneuria* sp. (stonefly)	>24,315	-
10	23,669	*Gammarus pseudolimnaeus* (amphipod)	23,669	-
9	>18,189	*Dugesia tigrina* (flatworm)	>18,189	-
8	>14,428	*Hybognathus amarus* (Rio Grande silvery minnow)	>14,428	-
7	9,205	*Salmo salar* (Atlantic salmon)	9,205	-
6	9,190	*Crangonyx pseudogracilis* (amphipod)	9,190	-
5	>7,547	*Oncorhynchus mykiss* (rainbow trout)	>7,547	-
		Oncorhynchus tshawytscha (chinook salmon)	>88,495*	-
4	>5,869	*Pimephales promelas* (fathead minnow)	>5,869	10.64
3	4,735	*Daphnia magna* (cladoceran)	4,735	12.19
2	4,370	*Asellus aquaticus* (isopod)	4,370	-
1	>2,604	*Ceriodaphnia dubia* (cladoceran)	>2,164	0.9590
		Ceriodaphnia sp. (cladoceran)	3,134	-

* SMAV for chinook salmon excluded from the GMAV for *Oncorhynchus*. See original text from LANS (2009) for details

Acute Criterion Calculations, without *T. tubifex*:

$$S^2 = \frac{\Sigma\,(\ln GMAV)^2 - (\Sigma \ln GMAV)^2/4}{\Sigma P - (\Sigma\sqrt{P})^2/4} = \frac{279.0413 - (33.3877)^2/4}{0.5882 - (1.4907)^2/4} = 10.8954 \qquad S = 3.3008$$

$$L = [\Sigma \ln GMAV - S(\Sigma\sqrt{P})]/4 = [33.3877 - 3.3008\ (1.4907)]/4 = 7.11681$$
$$A = S\ (\sqrt{0.05}) + L = (3.3008)(0.2236) + 7.11681 = 7.8549$$
$$\text{Final Acute Value} = FAV = e^{A} = 2{,}578.3211 \mu g/L$$

***Daphnia magna* studies (Biesinger and Christensen 1972; Kimball et al., manuscript)**: Both of these studies were discussed in the Gundersen Direct Testimony as not being valid for inclusion in the calculation of both acute and chronic aluminum criteria. In the case of the Kimball et al. manuscript, this was a thoroughly documented study in which aluminum concentrations were measured, and it was used by USEPA in development of the national aluminum AWQC (USEPA 1988)—the very same criteria that Amigos Bravos is recommending now be used in New Mexico. While pH did vary with aluminum concentration as pointed out by Amigos Bravos (*see* Gundersen Direct Testimony at 8), this study has been deemed acceptable for use by USEPA in developing both the existing national AWQC, as well as New Mexico's existing hardness-based criteria. Therefore, the Kimball et al. manuscript results should not be excluded for either *D. magna* or fathead minnows.

With respect to Biesinger and Christensen (1972), I provided the following explanation in the 2009 Triennial for its inclusion in derivation of the hardness-based aluminum criteria calculations:

> *As part of this update, a 16%-effect concentration (EC16) for reproductive effects in* D. magna *(Biesinger and Christensen 1972) was added to the chronic toxicity data set. The chronic toxicity value from Biesinger and Christensen (1972) was likely excluded in USEPA (1988) because Al test concentrations were not analytically verified. However, this study is included here because the chronic value is consistent with the corresponding measured value from the Kimball*

> *manuscript (which was an unpublished study used in the 1988 AWQC), thus reducing some of the uncertainty associated with the Al concentrations not being analytically verified. This study also provides additional useful information for deriving an ACR…* (*See* LANS 2009a at 4-5). And also: *This value is an EC16 for reproductive effects. It was included in Table 6 ("Other Data") of USEPA (1988), presumably because Al concentrations were not measured. However, it was included in Table 2 of this updated criteria evaluation because it provides information on the chronic sensitivity of* D. magna *in water of a moderate hardness (45.3 mg/L) and the result seems reasonable in comparison to the chronic value of 742.2 µg/L at a hardness of 220 mg/L (Kimball manuscript).* (*See* LANS 2009a, Table 2a at 17)

So while it is true that aluminum concentrations were not measured in this study, the data from Biesinger and Christensen (1972) were useful in providing data under conditions more likely to lead to greater aluminum toxicity (i.e., lower hardness than in the Kimball manuscript) which would provide a more conservative outcome overall. Until other data are published with daphnids with measured aluminum concentrations under these test conditions, I support inclusion of this study in the derivation of the New Mexico aluminum criteria.

- **Gundersen Comment**: *The use of data to derive parameters for the New Mexico acute equation (i.e. pooled-hardness slope) should not be applied to the chronic equation when peer-reviewed research indicates that the aluminum chronic toxicity mechanism differs from the acute mechanism* (*See* Gundersen Direct Testimony at 8-9).

Response: I disagree that the existing peer-reviewed scientific research suggests there are fundamentally different acute and chronic toxicity mechanisms for aluminum. As discussed in my own review paper (Gensemer and Playle 1999), it has been well established that there are two primary mechanisms of aluminum toxicity to aquatic organisms: 1) ionoregulatory disturbance from the binding of cationic aluminum species to the fish gill, and 2) respiratory distress from insoluble aluminum hydroxides clogging the gill surface, thereby limiting gas exchange. However, it is my opinion that the differences in which mechanism is most responsible for toxicity are not necessarily a factor of test duration or test endpoint (i.e., whether the test was "acute" or "chronic"), but rather, a function of pH and aluminum speciation. At more acidic pH where cationic forms of Al predominate in solution, ionoregulatory disturbance will be the most likely cause of toxicity. As pH reaches circumneutral conditions (i.e., pH ca. 6-8)—either in the exposure medium or in the gill microenvironment—insoluble forms of aluminum predominate, and so respiratory distress will be the most likely cause of toxicity.

Based on the results of Gundersen et al (1994), Amigos Bravos concludes that:

> *At alkaline pH, aluminum has more pronounced acute effects (lethal or severe effects) and at near neutral pH aluminum has more pronounced chronic effects (impacts a species over the species lifespan and can result in reproductive impacts), likely due to differences in aluminum species at near neutral versus alkaline pH* (See Gundersen Direct Testimony at 9).

In my opinion, it is not possible to conclude that this is purely a difference in the presence of aluminum species with pH because insoluble forms of aluminum dominated exposure concentrations over dissolved forms at both pH ranges tested (See Gundersen et al. 1994, Table 6 at 1352), particularly at the high concentrations needed to elicit toxicity when measured as "total" aluminum (See Gundersen et al. 1994. Figure 4 at 1352). In other words, effects observed at both pH values likely resulted from exposure to high concentrations of insoluble aluminum, which would have caused respiratory distress. Furthermore, some of the original studies cited in my review paper that demonstrated the presence and effects of respiratory distress from insoluble forms of aluminum used very short "acute" exposure systems (e.g., 24hr—Exley et al. 1996, or even 1-4 seconds—Playle and Wood 1990; See Gensemer and Playe 1999 for references). In fact, the biotic ligand model currently being considered by USEPA for derivation of aluminum criteria (which was developed based on the research I am participating in on behalf of the European Aluminum Association) treats both mechanisms equally—the amount of toxicity per amount of aluminum binding to the gill is no different whether the aluminum binds to the gill on the basis of a cation-anion interaction, or from insoluble forms clogging the gill surface.

Therefore, I find that because both mechanisms of aluminum toxicity—ionoregulatory disturbance and respiratory distress—have been observed using both acute and chronic exposures, that this is not a valid reason to dismiss application of the acute hardness slope to the chronic criteria equation as suggested by Amigos Bravos.

- **Gundersen Comment**: *Hardness has only a minor effect on aluminum toxicity and may not be protective at near-neutral to alkaline pH compared to other water-quality parameters (pH, DOC, temperature).* (*See* Gundersen Direct Testimony at 9).

Response: As noted in the 2009 Triennial direct testimony reports (LANS 2009a, GEI 2009), while we recognized that *overall* there is a significant effect of pH on aluminum toxicity, no significant statistical relationship could be observed based on the acceptable toxicity tests we reviewed over the pH range of 6.5 – 9.0. Therefore, whether or not pH had a statistically stronger effect than hardness in a single study (e.g., Gundersen et al. 1994) does not invalidate the lack of pH effect we observed from the multiple species and studies used in our analysis. As part of my work with the European Aluminium Association project team, we have developed and will soon be publishing a larger and more extensive database that evaluates the relative impacts of hardness vs. other water quality parameters (including the pH 6.0 data from Stubblefield et al. 2012). However, it is my opinion that these data do not *invalidate* the effects of hardness, but rather will include the additional effects of pH, DOC, and temperature. In other words, the existing hardness equation can still be considered *protective* of aquatic life over the pH range of 6.5 – 9.0, even if our ability to *predict* aluminum toxicity based on multiple water quality factors is improving as these new data are evaluated.

- **Gundersen Comment**: *Little data exists for aluminum toxicity at pH range 8.5 – 9.0* (*See* Gundersen Direct Testimony at 10).

Response: While this is a correct statement, this does not invalidate the fact that USEPA approved the New Mexico hardness-based criteria with full awareness of this limitation, and that Amigos Bravos' own suggestion to revert to the national AWQC for aluminum (USEPA 1988) effectively suffers from the same data limitation. Therefore, the outcome of Amigos Bravos' proposed solution does no more to correct this situation than the existing, and more scientifically reasonable, hardness-based aluminum criteria. Furthermore, while the effects of the aluminate anion ($Al(OH)_4^-$, which predominates aluminum speciation as pH increases beyond 8.5) on aluminum toxicity are indeed poorly known, recent studies suggest that aluminate will not bind strongly to the fish gill and, hence, not contribute to aluminum toxicity to a significant degree. Examples include Poléo and Hytterød (2003), who concluded that the toxicity of the aluminate ion to atlantic salmon was low at pH 9.5 (lower than the corresponding toxicity of cationic Al hydroxides) and Winter et al. (2005), who showed that aluminum accumulation on the gills of rainbow trout was lower at high pH (pH 10) owing to poor binding of the aluminate ion to the positively charged gill surface. Therefore, even though the toxicity of aluminate ions at high pH are not well known, the available evidence suggests it is not likely to be as bioavailable or as toxic as the forms of aluminum that exist within the more typical circumneutral to weakly alkaline pH range covered by the New Mexico hardness-based criteria.

- **Gundersen Comment**: *It is misleading to state that hardness (magnesium and calcium measured as $CaCO_3$) ameliorates aluminum toxicity when many scientific studies show that only calcium ameliorates aluminum toxicity* (*See* Gundersen Direct Testimony at 11).

  Response: It is not at all misleading to state that hardness ameliorates aluminum toxicity whether or not Mg contributes to the amelioration of toxicity as a function of hardness. This is because the hardness-toxicity relationship derived for the 2009 Triennial (LANS 2009a, GEI 2009) was based on the empirical relationships between measured water hardness and toxicity. Because calcium's contribution to hardness is clearly included in any empirical measurement of water hardness using standard analytical methods, any effects of Ca ions on toxicity will be incorporated into the relationship (i.e., the hardness slope of 1.3695). While most of the studies on aluminum toxicity I previously reviewed (Gensemer and Playle 1999) did indeed focus on Ca effects, this does not necessarily mean that Mg will have no effects on aluminum toxicity. In fact, I am not immediately aware of any studies that have independently studied the relative effects of Ca vs. Mg on aluminum toxicity as has been done for other metals such as copper (Welsh et al. 2000, Naddy et al. 2002). However, this is still logically irrelevant because if—as Amigos Bravos implies in this comment—only calcium ameliorates aluminum toxicity, then the presence of any Mg in exposure waters will have no impact on the resulting empirical relationship between hardness and toxicity.

III. CONCLUSIONS

Based on my review of the Gundersen Direct Testimony and my knowledge of the scientific literature related to the toxicity of aluminum, I conclude that it is not scientifically valid to accept Amigos Bravos' proposal to revert to the outdated USEPA national AWQC values of 750 and 87 µg Al/L (USEPA 1988). Doing so ignores more recent scientific studies conducted since development of the 1988 national AWQC that demonstrate the protective effects of water hardness on aluminum toxicity. Reverting back to these outdated criteria also ignores the extensive technical review conducted by NMED and USEPA in the 2009 Triennial, which lead to USEPA approval of the existing hardness-based criteria as being protective of New Mexico's aquatic life over the pH range of 6.5 – 9.0. Amigos Bravos had numerous opportunities to comment on these aluminum criteria during the 2009 Triennial Review, and virtually all of the studies cited in the Gundersen Direct Testimony were not only available for review, but known and considered by the proponents (CMI and LANS), NMED, and USEPA.

In my rebuttal testimony, I have conclusively demonstrated that the weight of scientific evidence supports the existing hardness-based criteria as being protective of aquatic life, even as we continue to learn more about the effects of other water quality factors on aluminum toxicity (specifically, pH, dissolved organic carbon, and temperature). I am fully aware that USEPA is currently working on updates to the national AWQC for aluminum based in large part on the additional studies provided to them by the European Aluminium Association team of which myself and GEI have been active participants for several years. However, it is my professional opinion that these new studies do not invalidate the effects of hardness on aluminum toxicity, and that the existing New Mexico hardness-based aluminum criteria are adequately protective of aquatic life at the levels intended under the federal Clean Water Act and the New Mexico Water Quality Act. Therefore, I urge the WQCC to reject Amigos Bravos' proposal to repeal the current hardness-based aluminum criteria under 20.6.4.900 NMAC in favor of the outdated 1988 national AWQC for aluminum (USEPA 1988).

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STATE OF NEW MEXICO
BEFORE THE WATER QUALITY CONTROL COMMISSION

IN THE MATTER OF THE TRIENNIAL REVIEW OF STANDARDS FOR INTERSTATE AND INTRASTATE SURFACE WATERS, 20.6.4 NMAC

WQCC No. 14-05(R)

AFFIDAVIT OF ROBERT W. GENSEMER, Ph.D.

STATE OF COLORADO)
) ss.
COUNTY OF DENVER)

I, Robert W. Gensemer, Ph.D., being first duly sworn, depose and state that I am the individual whose prepared Rebuttal Testimony accompanies this Affidavit, and that said Rebuttal Testimony is true and correct to the best of my knowledge and belief.

Robert W. Gensemer, Ph.D.

SUBSCRIBED AND SWORN TO before me this 12th day of February 2015.

Sharon Korver
Notary Public

SHARON KORVER NOTARY PUBLIC STATE OF COLORADO

My Commission Expires: April 30, 2015.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

January 30, 2014

Mr. Scott G. Mandirola, Director
Division of Water and Waste Management
West Virginia Department of Environmental Protection
601 57th Street, SE
Charleston, West Virginia 25304

Dear Mr. Mandirola:

Thank you for soliciting EPA's views on the West Virginia Department of Environmental Protection (WVDEP) proposed revision of statewide aluminum water quality criteria for the protection of aquatic life. As you may know, EPA is in the process of updating the existing Clean Water Act Section 304(a) criteria recommendations for aluminum. EPA's updated criteria will reflect consideration of the latest scientific information on aluminum toxicity, including new data on mussels' sensitivity and pH effects on aluminum toxicity.

EPA encourages West Virginia to monitor the latest research and any updates to EPA's 304(a) aluminum criteria in order to ensure that West Virginia's criteria are based on sound scientific rationale and are protective of aquatic life. As such, WVDEP should consider whether the proposed criteria are protective of mussels in West Virginia, as well as appropriately take into consideration potential pH interactions with aluminum toxicity, as well as hardness. EPA believes the results of the on-going research on aluminum toxicity will provide valuable information to aid West Virginia in development of an appropriate statewide aluminum criteria revision.

EPA reviewed West Virginia's proposed revisions to the aluminum criteria in 47CSR2 "Requirements Governing Water Quality Standards," and provided comments on July 29, 2013, asking West Virginia to consider a list of the latest studies on aluminum toxicity to aquatic life. EPA also shared West Virginia's revisions with the U.S. Fish and Wildlife Service (USFWS), who provided comments on July 19, 2013, expressing concerns regarding aluminum toxicity to mussel species, including federally listed endangered mussels, in West Virginia and citing two studies on impacts to mussels exposed to aluminum. EPA asked West Virginia to consider the concerns raised by USFWS, particularly since West Virginia has a high diversity of native freshwater mussels. Finally, on November 26, 2013, EPA sent West Virginia an in-depth analysis comparing the studies West Virginia considered in calculating the draft aluminum revisions, with studies EPA believes may inform the revised national 304(a) recommendations for aluminum.

GENSEMER TESTIMONY
EXHIBIT 8

Information provided by USFWS indicates that mussels may be more sensitive to the effects of aluminum than other organisms for which EPA currently has data. The Kadar et al. (2001) study that USFWS included in their analysis indicated that adult *Anodonta cygnea* mussels may be sensitive to aluminum at concentrations above 250 µg/L, with reductions in mean duration of shell opening of 50% at 500 µg/L aluminum in the water column (at circumneutral pH) when compared to paired controls. This suggests that chronic elevated aluminum concentrations could lead to feeding for shorter durations with potential implications for survival and growth, and possibly even reproduction. Pynnönen (1990) conducted toxicity tests with two freshwater mussels in the Unionidae family (*Anodonta anatina* and *Unio pictorum*). In both species, pH had a significant effect on accumulation of aluminum in the gills, while hardness in the water was of minor importance, supporting USFWS conclusions that hardness-based criteria alone (without additional consideration of pH) will not be protective of mussels. The *Anodonta* mussel species in the two studies described above are not native to the US, but there are mussel species of the *Anodonta* genus present in West Virginia, including *Anodonta suborbiculata*, listed as a rare, threatened or endangered species in the West Virginia Department of Natural Resources' Rare, Threatened, and Endangered Animal listing that can be found at: (http://www.wvdnr.gov/Wildlife/PDFFiles/RTE_Animals_2012.pdf)

Finally, EPA recently became aware of another study, Simon 2005, that was conducted on mussels native to West Virginia and corroborates the evidence from the mussel studies provided by USFWS. In this 21-day chronic aluminum toxicity test conducted at circumneutral pH with the juvenile mussel *Villosa iris*, growth was significantly reduced at aluminum levels above 337 µg/L.

EPA believes that these studies provide a sufficient weight of evidence to indicate mussels may be more sensitive to aluminum exposure than other species in West Virginia's data set. West Virginia's proposed revisions to their existing aluminum criteria currently do not take into account potential impacts on mussels and a rationale for the exclusion of these potential effects has not been provided. The proposed chronic criteria values generated using West Virginia's proposed hardness-based equation are approximately three to six times higher than the chronic criteria value recommended as protective of mussel species by USFWS, at approximately median hardness ranges for West Virginia. As the USFWS noted in their letter, the state has a high diversity of mussel species, with 62 mussel species present throughout the state, including 10 federally listed species. EPA believes protection of these resources should be an important consideration in the derivation of any new water quality criteria for the protection of aquatic life in West Virginia.

Because of the concern of mussel sensitivity to aluminum, EPA will be looking for additional data to refine our estimates of aluminum toxicity to mussels. In addition, aluminum experts with whom EPA has consulted have indicated that pH is also a critical factor that should be taken into account in developing an aluminum criteria equation. By spring 2014, EPA expects to receive additional data about pH interactions with aluminum toxicity across a range of species, as well as the results of mussel toxicity tests with aluminum. EPA will consider this information to ensure that the national 304(a) aluminum criteria update will be protective of all aquatic life, including mussels, at various pH and hardness levels.

EPA appreciates WVDEP's commitment to protecting water quality, and remains supportive of WVDEP's consideration of new data and information to revise its existing aluminum criteria. If you have any questions concerning this letter, please contact me at (215)814-5717, or have your staff contact Denise Hakowski at (215)814-5726.

Please note that our comments above are preliminary in nature and do not constitute a final decision by EPA under Clean Water Act § 303(c). Approval/disapproval decisions will be made by the Region following adoption of any new/revised standards by the state and submittal to EPA. Any determination pursuant to Clean Water Act § 303(c)(4)(B) may only be made by the Administrator or her duly authorized delegate.

Sincerely,

Evelyn S. MacKnight

Evelyn S. MacKnight
Associate Director
Office of Standards, Assessment & TMDLs
Water Protection Division

cc: Kevin Coyne (WVDEP)

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WATER QUALITY CONTROL COMMISSION

STATE OF NEW MEXICO
BEFORE THE WATER QUALITY CONTROL COMMISSION

IN THE MATTER OF TRIENNIAL REVIEW OF STANDARDS FOR INTERSTATE AND INTRASTATE SURFACE WATERS, 20.6.4 NMAC

WQCC No. 14-05(R)

CERTIFICATE OF SERVICE

I hereby certify that a true and correct copy of *Rebuttal Testimony of Robert W. Gensemer, Ph.D. GEI Consultants, Inc.* was sent via electronic email and/or hand delivered to the following counsel of record:

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