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FINAL Lead Recalculation Report to Support Implementation of the Los Angeles River and Tributaries Metals TMDL

submitted to:

LOS ANGELES RIVER METALS TMDL IMPLEMENTATION GROUP

prepared by:

LARRY WALKER ASSOCIATES

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GLOSSARY OF ACRONYMS

µg/L	Micrograms per Liter
ACR	Acute-to-Chronic Ratio
BPA	Basin Plan Amendment
BWC	Burbank Western Channel
BWRP	Burbank Water Reclamation Plant
$CaCO_3$	Calcium Carbonate
CCC	Criterion Continuous Concentration
CEQA	California Environmental Quality Act
CF	Conversion Factor
CFR	Code of Federal Regulations
cfs	Cubic feet per second
CMC	Criterion Maximum Concentration
CTR	California Toxics Rule {Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule}
EC20	The concentration which adversely affects 20% of the test species.
EC50	Median Effect Concentration. The concentration which adversely affects 50% of the test species.
FACR	Final Acute-to-Chronic Ratio
FAV	Final Acute Value
FCV	Final Chronic Value
GMAV	Genus Mean Acute Value
kg/day	Kilogram per Day (load)
LA	Los Angeles
LAGWRP	Los Angeles-Glendale Water Reclamation Plant
LAR	Los Angeles River
LARWQCB	Los Angeles Regional Water Quality Control Board
LC50	Median Lethal Effect Concentration. The estimated concentration resulting in 50% mortality.
mg/L	Milligrams per Liter
MATC	Maximum Acceptable Toxicant Concentration
MDR	Minimum Data Requirements
MS4	Municipal Separate Storm Sewer System
P	Cumulative Probability
Pb	Lead
POTW	Publicly Owned Treatment Works
R	Rank
SMACR	Species Mean Acute-to-Chronic Ratio
SMAV	Species Mean Acute Value
SMCV	Species Mean Chronic Value
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Loads
USEPA	United States Environmental Protection Agency
WER	Water-Effect Ratio
WLA	Waste Load Allocation
WQC	Water Quality Criteria

Executive Summary

The Los Angeles River and Tributaries Total Maximum Daily Load (TMDL) for Metals became effective October 29, 2008. The implementation schedule in the TMDL Basin Plan Amendment (LARWQCB 2007) allows time for special studies that may serve to refine the estimate of loading capacity, waste load and/or load allocations, and other studies that may serve to optimize implementation efforts. The *Work Plan for Recalculation and Water-Effect Ratio to Support Implementation of the Los Angeles River and Tributaries Metals TMDL* (Work Plan) (LWA 2010) was developed to support special studies to evaluate the targets for copper and lead. The recommended approach for developing appropriate lead criteria for consideration in the Metals TMDL is the USEPA Recalculation Procedure.

The Recalculation Procedure allows for incorporation of updates or revisions to the lead (Pb) criteria data set (not necessarily site-specific updates) utilized in the Metals TMDL. An approved lead toxicity test dataset that meets the minimum data requirements and water quality criterion calculation data requirements was provided by USEPA (USEPA 2008). As the entire approved USEPA dataset was utilized, the recalculation of the lead criteria results in a de facto recalculation of the national criteria and could be applied to the entire Los Angeles region upon completion of a species of interest analysis in other watersheds, if so desired. The criteria equations developed herein may be utilized to adopt site-specific lead objectives for the Los Angeles River and tributaries and/or revise the TMDL targets and allocations. However, this report does not consider the additional requirements for such a regulatory action. Rather, the report presents and documents the calculation of lead criteria consistent with USEPA's Recalculation Procedure.

USEPA methods for the Recalculation Procedure and criteria derivation were utilized to calculate the following updated lead final acute value (FAV) and final chronic value (FCV) and provide updates to the corresponding dissolved lead criteria equations:

$$\text{Final Acute Equation}_{\text{Dissolved}} = (1.46203 - \ln(\text{hardness}) * 0.145712) * e^{1.466*\ln(\text{hardness})-1.882}$$

$$\text{Final Chronic Equation}_{\text{Dissolved}} = (1.46203 - \ln(\text{hardness}) * 0.145712) * e^{1.466*\ln(\text{hardness})-3.649}$$

By applying the Final Acute and Final Chronic Equations, it was possible to calculate acute and chronic criterion values at various hardness concentrations found in the LA River (**Table ES-1**). Species of interest were identified for the waterbodies subject to the TMDL, and based on the available data, the acute and chronic criterion are protective of those species.

Table ES-1 Summary of Lead Water Quality Criteria Resulting from Recalculation

Hardness	Acute/CMC (µg/L)		Chronic/CCC (µg/L)	
	Dissolved	Total	Dissolved	Total
50	42	47	7.2	8.1
100	103	130	18	22
200	248	359	42	61
300	411	651	70	111
400	585	993	100	170

1 Introduction

The Los Angeles River and Tributaries Total Maximum Daily Load (TMDL) for Metals was originally adopted on June 2, 2005 by the Los Angeles Regional Water Quality Control Board (LARWQCB), approved by the United States Environmental Protection Agency (USEPA) on December 22, 2005, and became effective on January 11, 2006. In conformance with a Los Angeles County Superior Court writ of mandate, the LARWQCB was required to perform a California Environmental Quality Act (CEQA) alternatives analysis. A revised TMDL with alternatives analysis was prepared, circulated, and adopted by the LARWQCB on September 6, 2007 and adopted by the State Water Resources Control Board (SWRCB) on June 17, 2008. The effective date of the current Los Angeles River and Tributaries Metals TMDL is October 29, 2008. The TMDL was amended in 2010 to incorporate a water-effect ratio (WER) for copper into the waste load allocations (WLAs) for the three water reclamation plants in the watershed. The TMDL was developed to address metals listings presented in the 1998 and 2002 303(d) lists as well as any additional listings identified during TMDL development and subsequently added to the 2004/2006 303(d) list. Listings included copper, lead, zinc, cadmium and selenium.

The implementation schedule in the TMDL Basin Plan Amendment (BPA) (LARWQCB 2007) allows time for special studies that may serve to refine the estimate of loading capacity, waste load and/or load allocations, and other studies that may serve to optimize implementation efforts. The *Work Plan for Recalculation and Water-Effect Ratio to Support Implementation of the Los Angeles River and Tributaries Metals TMDL* (Work Plan) (LWA 2010) was developed to support special studies to evaluate the targets for copper and lead. The Work Plan was submitted to the LARWQCB in March 2010 and was approved by the Executive Officer on February 24, 2011. The Los Angeles River Metals TMDL Implementation Group has taken the lead role in the implementation of the Work Plan, which details the approach to developing a copper WER and a recalculation of the lead criteria. As presented in the Section 3.4.1 of the Work Plan, the recommended approach for developing appropriate lead criteria for consideration in the Metals TMDL is the Recalculation Procedure. The following sections describe how the Recalculation Procedure was used to recalculate the lead criteria. The criteria developed herein may be utilized to adopt site-specific lead objectives for the Los Angeles River and tributaries and/or to revise the TMDL targets and allocations. However, this report does not consider the additional requirements for such a regulatory action. Rather, the report presents and documents the calculation of lead criteria consistent with USEPA's Recalculation Procedure.

Table 1 presents the Los Angeles River (LA River or LAR) reaches and tributaries listed for lead on the 1998, 2002, and 2004/2006 303(d) lists and the dry-weather lead TMDL targets and WLAs assigned to municipal separate storm sewer system (MS4) permittees. Dry-weather targets are based on the California Toxics Rule (CTR, USEPA 2000) criterion maximum concentration (CMC), also known as the acute criterion. Wet-weather TMDL targets are based on the CTR criterion continuous concentration (CCC), also known as the chronic criterion. The CTR CMC and CCC are presented as dissolved criteria equations as follows:

$$CMC_{\text{Dissolved Lead}} = \text{WER x (Acute Conversion Factor) x } (e^{(m_A[\ln(hardness)]+b_A})$$

$$CCC_{\text{Dissolved Lead}} = \text{WER x (Chronic Conversion Factor) x } (e^{(m_C[\ln(hardness)]+b_C})$$

Where:

WER = Water-Effect Ratio equal to default of 1 in the absence of a site-specific study
m_A= acute pooled slope
b_A = criterion maximum intercept
m_C= chronic pooled slope (which may be equal to m_A)
b_C = final chronic intercept

Dry and wet-weather targets were calculated based on representative hardness values. For dry-weather, hardness values for individual waterbodies were utilized to calculate dissolved[1] targets using the chronic CTR equation, and the default CTR conversion factor was utilized to translate the dissolved target into a total target. For wet-weather, a single hardness value was utilized to calculate a dissolved target using the acute CTR equation for all reaches and tributaries.[2] A site-specific translator was utilized to translate the dissolved target to a total target. Dry-weather WLAs were assigned to all LA River reaches and tributaries based on the critical flow condition and the chronic CTR total targets. Additionally, WLAs were assigned to reaches and tributaries upstream of reaches with listings. The MS4 wet weather WLA was based on the acute CTR total target, has units of kg/day as total recoverable metal, and is expressed by the following equation: WER x 5.6×10^{-8} x daily volume in L – 3.85. This WLA was set equal to the total loading capacity during wet-weather minus the load allocations for open space, direct air deposition, and the WLAs for publicly owned treatment works (POTWs).

Table 1. Los Angeles River Metals TMDL Dry Weather Listings, Targets, and Allocations for Lead

Los Angeles River (LAR) Reaches and Tributaries	**Lead Listings** [a]	**Critical Flow** [b] (cfs)	**Target** [b] (µg/L)	**MS4 Allocation** [b] (kg/day)
LAR Reach 1	X	2.58	12	0.07
LAR Reach 2	X	3.86	11	0.07
LAR Reach 3	X	4.84		0.03
above and below LAGWRP			12	
LAR Reach 4	X	5.13	10	0.12
LAR Reach 5	X	0.75	19	0.03
LAR Reach 6		7.2	19	0.33
Arroyo Seco		0.25	11	0.01
Bell Creek		0.79	19	0.04
Burbank Western Channel		3.3		0.07
above BWRP			14	
below BWRP			9.1	
Compton Creek	X	0.9	8.9	0.02
Monrovia Canyon Creek	X		8.2	
Rio Hondo Reach 1	X	0.5	5	0.006
Tujunga Wash		0.03	10	0.0002
Verdugo Wash		3.3	12	0.1

[a] Listings identified on the 1998, 2002, and 2004/2006 303(d) lists.
[b] Total lead targets and allocations obtained from LA River Metals TMDL Basin Plan Amendment (LARWQCB 2010).
LAGWRP – City of Los Angeles Glendale Water Reclamation Plant
BWRP – City of Burbank Water Reclamation Plant

[1] Dissolved metal is operationally defined as that which passes through a 0.45-µm filter (USEPA 1996).
[2] Wet weather was defined within the TMDL as when the daily maximum flow at Wardlow Road is equal to or greater than 500 cfs.

2 Background

The USEPA publishes national water quality criteria (WQC) for the protection of aquatic life consisting of a concentration, an averaging period, and a return frequency. The WQC for the protection of aquatic life are calculated mostly from laboratory-derived toxicity data. The USEPA compiles data from acceptable toxicity tests, which have been conducted in laboratory or well-characterized dilution water, from a wide range of species. Criteria are developed from the compiled data using the approach outlined in *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* (Criteria Guidelines) (USEPA 1985a). The Criteria Guidelines provide methods for calculating both acute and chronic criteria.

National WQC are intended to protect 99% of individuals in 95% of the species in aquatic communities from acute and chronic effects resulting from exposure to a chemical stressor in all waters of the United States (USEPA 1986). However, the Code of Federal Regulations (CFR) 40 CFR 131.11(b)(1)(ii) allows States to establish WQC that are "… modified to reflect site-specific conditions." The Water Quality Standards Handbook (USEPA 1994a) states that:

> *Site-specific criteria, as with all water quality criteria, must be based on a sound scientific rationale in order to protect the designated use. Existing guidance and practice are that EPA will approve site-specific criteria developed using appropriate procedures.*

Site-specific criteria are intended to provide the same level of protection intended for aquatic life as the national criteria but at a specific site. Hence, derivation of site-specific criteria does not change the intended level of protection. A "site" may be defined as all waters in the state, region, watershed, or, as a specific waterbody or segment of waterbody (USEPA 1994a). The Water Quality Standards Handbook (USEPA 1994a) presents three procedures for deriving site-specific criteria:

1. Recalculation Procedure. This method is intended to take into account relevant differences between the sensitivity of species in the national dataset and those at the Site. However, Recalculation can consist of any updates or revisions in the data set (not necessarily site-specific updates) and therefore be conducted such that it is effectively an update to the national WQC.
2. Water-Effect Ratio Procedure. This method provides for the use of a water-effect ratio to take into account observed differences between the toxicity of a chemical in laboratory dilution water and in site water.
3. Resident Species Procedure. This method is intended to take into account differences for both the aquatic organisms present at a site and differences in toxicity of site water and lab water.

As discussed in Section 3.4.1 of the Work Plan, the Recalculation Procedure is the recommended approach for developing appropriate lead criteria for consideration in the Metals TMDL primarily for the following reasons: 1) the lead WQC that are incorporated into the CTR and form the basis of the lead TMDL targets and allocations have not been revised since 1984; 2) the 1984 lead WQC encompass comparatively few genus mean acute values (GMAVs) compared to other metals criteria; and, 3) an updated lead toxicity dataset was provided by USEPA that could be used to recalculate the lead criteria. The USEPA Ambient WQC for Lead (USEPA 1985b) was published in 1984. WQC documents are developed using toxicity data from USEPA validated studies that were conducted using knowledge of, and experiments on, the characteristics of the compounds in water, and that met the test acceptability standards established by the Criteria Guidelines (USEPA 1985a). USEPA translates the ecotoxicological data reported in these studies into national criteria. The 1984 lead criteria document utilized 23 measured freshwater LC50s[3] resulting in the calculation of 10 species mean acute values (SMAVs) which also represented the 10 GMAVs utilized to calculate the freshwater acute criterion. At the time the lead WQC were published, comparatively few lead toxicity studies were available to generate the 10 GMAVs used to calculate the freshwater lead acute WQC compared to other metals of concern (e.g., 41 and 35 GMAVs used to calculate the copper (USEPA 1985c) and zinc (USEPA 1987) aquatic life criteria, respectively).

Following the publication of WQC documents, studies continued to be conducted that provide additional information for previously tested species and new information on additional species or water quality conditions that impact the criteria. These studies, and the additional aquatic toxicity data reported therein, occasionally create the need to update the national WQC. In this case, the lead WQC have not been revised since 1984 (more than 27 years), include comparatively few GMAVs, and therefore are in need of revision.

As presented in the following section, the Recalculation Procedure provides an approach for recalculating, and therefore updating, the national lead WQC. The Recalculation Procedure has been utilized to develop WQC that have been approved by USEPA, namely, cyanide WQC in San Francisco Bay (CRWQCB 2006) and cadmium WQC in Colorado (CEC 2004).

2.1 RECALCULATION PROCEDURE

The Recalculation Procedure provides a method for adjusting the national dataset used to develop criteria based on more recent studies and/or for species that are present in the waterbody (i.e., those species that occur or are expected to occur at the Site). Appendix B of the *Interim Guidance on Determination and Use of Water-Effect Ratios for Metals* (USEPA 1994b), referred to herein as the "Interim Guidance," and the 1997 updates to the Recalculation Procedure (*A Change in the Recalculation Procedure and Optional Consideration of Life Stage When the Recalculation Procedure is Used* (USEPA 1997) [4], outline the Recalculation Procedure, which consists of the following six steps.

A. Corrections are made to the national dataset. Note that only corrections approved by USEPA may be made.
B. Additions are made to the national dataset. Note that only additions approved by USEPA may be made.
C. The deletion process may be applied if desired.

[3] The LC50 is the 50% (Median) Lethal Concentration, i.e., the concentration which results in the mortality of 50% of the test species.
[4] The 1997 update to the Recalculation Procedure addresses considerations for deleting species from the dataset. This update was reviewed, but did not result in any additional changes because no species were deleted from the USEPA 2008 dataset.

D. If the new dataset does not satisfy the applicable Minimum Data Requirements (MDRs), additional pertinent data must be generated; if the new data are approved by the USEPA, the Recalculation Procedure must be started again at step B with the addition of the new data.
E. The new criterion maximum concentration (CMC) or criterion continuous concentration (CCC) or both are determined. The CMC and CCC are generally referred to as the acute and chronic criterion, respectively.
F. A report is written.

The first four steps (A, B, C, and D) are utilized to develop an appropriate dataset that satisfies the MDRs as outlined in the Criteria Guidance. Steps A and B are required, while step C is optional and can be used if desired for further modification of the dataset. Steps E and F are the process of using the dataset to generate new WQC and a report for review, respectively. The following section details how the Recalculation Procedure was used to update the lead criteria.

3 Recalculation of Lead Criteria

The primary mechanism for metals toxicity (including lead) to organisms that live in the water column is by interaction with the gills. Additionally, metal toxicity is affected by calcium and magnesium cations. These effects are primarily accounted for by using hardness as a surrogate to modify toxicity estimates for many metals (USEPA 2008; USEPA 2005). Given these two factors, the CTR presents the CMC and CCC as dissolved criteria equations based on hardness, as discussed in Section 1 above. The dissolved criteria equations include a conversion factor (CF), as the lead toxicity data utilized to calculate the criteria were primarily reported as total recoverable metal. The lead CF is hardness dependent. [5]

The recalculation approach can result in an update to each of the factors within the CMC and CCC equations except for the WER, which must be based on a site-specific study. The following recalculation is intended to update the dissolved CTR CMC and CCC equations. The resulting dissolved equations can then be used to calculate total lead criteria utilizing either the default CTR conversion factors or site-specific translators.

The Interim Guidance states that a list of approved toxicity data will be available from the USEPA for constituents for which USEPA has developed criteria. An approved lead toxicity test dataset that meets the MDRs and WQC calculation data requirements was provided by USEPA on October 28, 2008. These data were made available by USEPA for this study in the form of the draft *Ambient Aquatic Life Water Quality Criteria for Lead* (USEPA 2008) document that includes tables containing acute and chronic toxicity data acceptable for criteria derivation. The following sections describe the updated data (also referred to as the approved dataset) as well as the calculation of both the CMC and CCC criteria utilizing the criteria calculation procedures outlined in the Criteria Guidelines, per the Recalculation Procedure. These calculations were performed to recalculate the lead criteria at the site of interest. “The Site” is defined as the urbanized areas of the Los Angeles River watershed, and is illustrated in **Figure 1**. Differences between the USEPA 2008 document and this report are summarized in Section 3.4.

[5] For lead, the acute and chronic conversion factor equations are the same.

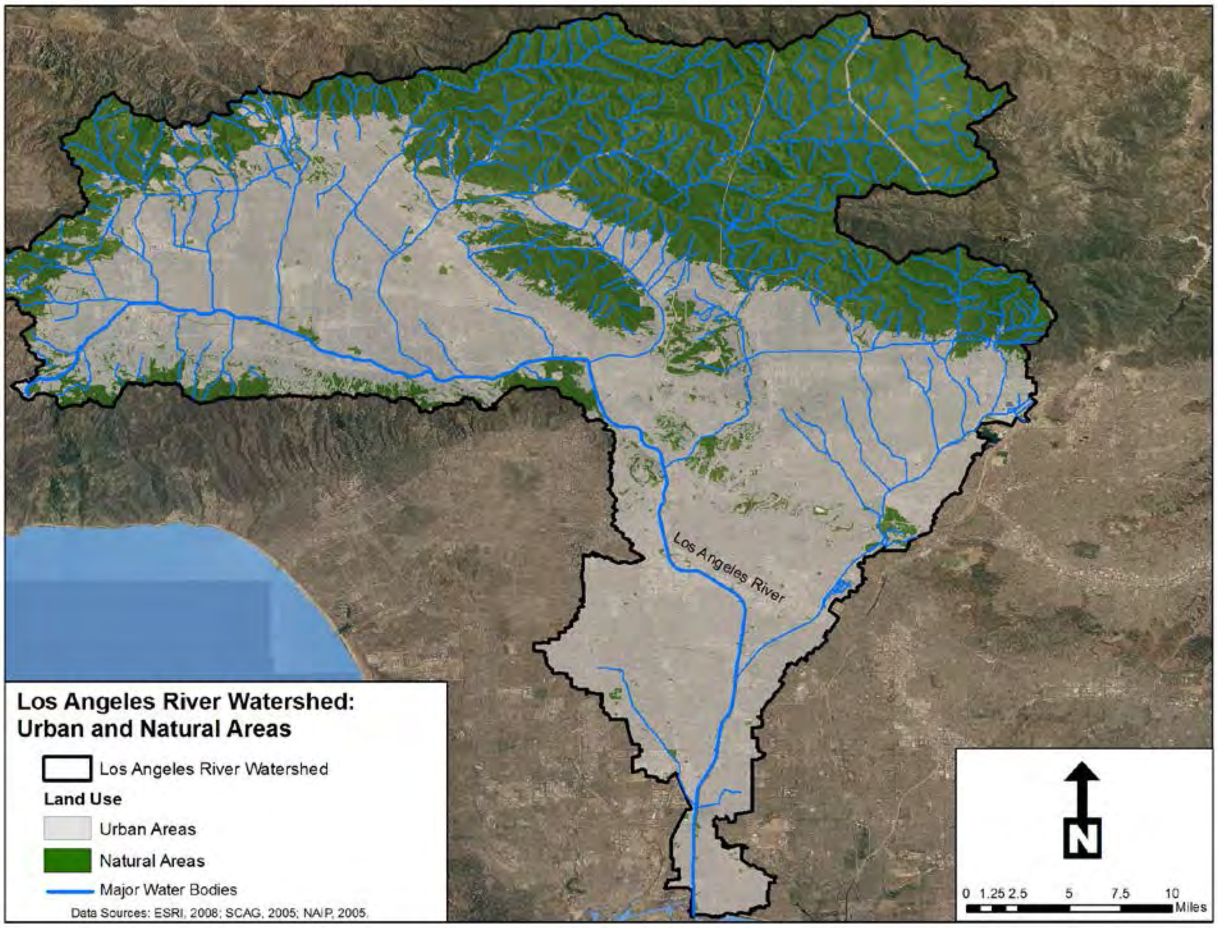

Figure 1. Boundaries of the Site being considered for Lead Criteria Recalculation

3.1 RECALCULATION OF ACUTE CRITERION

As stated previously, the CTR provides the following equation for the calculation of the dissolved lead CMC, also referred to as the acute criterion:

$$CMC_{\text{Dissolved Lead}} = WER \times (\text{Acute Conversion Factor}) \times (e^{(m_A[\ln(\textit{hardness})]+b_A)})$$

Where:

CMC = Criterion Maximum Concentration for dissolved lead
WER = Water-Effect Ratio equal to 1 in the absence of a site-specific study
Acute Conversion Factor = 1.46203 – ln(hardness)*0.145712
m_A= pooled slope
b_A = criterion maximum intercept

The recalculation approach can result in an update to each of the factors within the CMC equation except for the WER, which must be based on a site-specific study. The following discusses the use of the 2008 USEPA data set in recalculating the CTR acute criterion.

3.1.1 Updated Acute Dataset

The 1984 lead criteria document identified 23 acceptable measured freshwater acute data points (LC50s or EC50s[6]). By comparison, acceptable data on the acute effects of lead in freshwater are currently available for 18 species of invertebrates and 14 species of fish (**Appendix A**). Data were determined to be "acceptable" when the acute tests met the requirements of the Criteria Guidelines and SMAVs could be calculated. These species satisfy the eight different family requirements specified in the Criteria Guidelines. The approved dataset includes 103 measured freshwater acute values from 45 studies, including data for 39 species.

No species were deleted from the USEPA-approved acute dataset to conduct the lead recalculation in this report; there are, however, a few differences between the data reported in USEPA 2008 and the data utilized herein. Please see Section 3.4 for the discussion of differences.

3.1.2 Updated Acute Hardness Relationship

Correlation with water hardness is the primary quantitative correction factor used to modify toxicity estimates for many metals (USEPA 2008; USEPA 2005). Water hardness is used as a surrogate for the cations calcium and magnesium, which affect the results of toxicity tests on lead. Because water hardness is a surrogate, the numbers obtained through this correction are approximations of the true toxicity. To estimate the relationship between lead toxicity and water hardness, an analysis of covariance was performed on the approved dataset using the S-Plus (Insightful Corporation, Seattle, WA) software program. This analysis was used to calculate the pooled slope for hardness using the natural logarithm of the total lead acute value as the dependent variable, species as the treatment or grouping variable, and the natural logarithm of hardness as the covariate or independent variable. The analysis of covariance model was fit to the data for the five species for which definitive acute values were available over a range of hardness values. The range in hardness was one in which the highest hardness in test water for a given species was at least three times the lowest hardness tested for that species, and where the highest hardness value in test water was at least 100 mg/L higher than the lowest hardness value in test water. An F-test showed that, under the assumption of equality of slopes, the probability of obtaining five slopes as dissimilar as these by chance is P=0.8988. This was interpreted as indicating that it is reasonable to assume that the slopes for these five species are the same (see **Table 2**). Based on these results, the pooled slope of 1.466 was used to adjust all acute values to a common hardness (i.e., 50 mg/L as $CaCO_3$). Test results for all other species either did not meet the above data requirements or did not show any hardness toxicity trends because of differences in exposure methods, age, etc.

[6] The EC50 is the 50% (Median) Effect Concentration, i.e., the concentration which adversely affects 50% of the test species.

Table 2. Results of Covariance Analysis of Freshwater Acute Toxicity versus Hardness

Species	n	Slope	Comment	95% Confidence Limits	Degrees of Freedom
Daphnia magna	8	0.8415		-0.8872, 2.5702	6
Rainbow trout	5	1.8868		-1.7323, 5.5059	3
Fathead minnow	4	1.5492		0.1314, 2.9670	2
Bluegill	2	1.0108		(Cannot be calculated)	0
Carp	5	1.5619		-0.1397, 3.2635	3
All of the above	24	1.4658	a	0.8735, 2.0581	18

[a] P = 0.8988 for equality of slopes

3.1.3 Recalculated Acute Criterion

Sections IV and V of the Criteria Guidelines present the approach to determining the final acute value (FAV) and final acute equation, respectively. The first eight steps of determining the FAV focus on developing an appropriate dataset. As the entire USEPA-approved acute dataset was utilized, the process for calculating the FAV for this effort starts at the ninth step (step I in Section IV of the Criteria Guidelines, and renumbered below) as follows:

1. Step I: For each species for which at least one acute value is available, the SMAV should be calculated as the geometric mean[7] of the results.
2. Step J: For each genus for which one or more SMAVs are available, the GMAV should be calculated as the geometric mean of the SMAVs available for the genus.
3. Step K: Order the GMAVs from high to low.
4. Step L: Assign ranks, R, to the GMAVs from "1" for the lowest to "N" for the highest. If two or more GMAVs are identical, arbitrarily assign them successive ranks.
5. Step M: Calculate the cumulative probability, P, for each GMAV as R/(N+1).
6. Step N: Select the four GMAVs that have cumulative probabilities closest to 0.05 (if there are fewer than 59 GMAVs, these will always be the four lowest GMAVs).
7. Step O: Using the selected GMAVs and Ps, calculate the FAV based on equations specified in the Criteria Guidelines (listed for convenience in **Figure 2**, below).
8. Step P: If for a commercially or recreationally important species the geometric mean of the acute values from flow-through tests in which the concentrations of the test material were measured is lower than the FAV, then that geometric mean should be used as the FAV instead of the calculated FAV.

The CMC is then set equal to one-half of the FAV (CMC = FAV/2) as stated in Section XI of the Criteria Guidelines, as a safety factor to avoid lethality during short-term exposures[8]. A final acute equation is developed when enough data are available to show that acute toxicity to two or

[7] The geometric mean of N numbers is the Nth root of the product of the N numbers.
[8] Per the Criteria Guidelines, the CMC is intended to protect 95% of a group of diverse genera. Dividing the FAV by 2 is intended to result in a concentration that will not severely adversely affect too many of the organisms (USEPA 1985a, page 17).

more species (represented by at least one fish and one invertebrate) are similarly related to a water quality characteristic (e.g., hardness) as described in **Section 3.1.2**.

Table 3 and **Table 4** present the ranked GMAVs. Following the tables, **Figure 2** presents the calculations of the FAV for total lead at a hardness of 50 mg/L. As discussed in **Section 3.1.2**, an analysis of covariance was performed and a pooled slope was determined to adjust acute toxicity values on the basis of hardness for each individual data point prior to calculating the GMAV.

Table 3. GMAVs for Total Lead at Hardness of 50 mg/L

Genus	GMAV[a] (µg/L)	Rank	P	$\sqrt{P}$	$\ln GMAV$	$(\ln GMAV)^2$
Diaptomus	72.07	1	0.0345	0.1857	4.278	18.30
Gammarus	144.3	2	0.0690	0.2627	4.972	24.72
Ceriodaphnia	147.4	3	0.1034	0.3216	4.993	24.93
Lecane	164.7	4	0.1379	0.3713	5.104	26.05
Daphnia	174.9	5	0.1724	0.4152	5.164	26.67
Cyclops	215.2	6	0.2069	0.4549	5.372	28.85
Hyalella	227.3	7	0.2414	0.4913	5.426	29.44
Micropterus	548.6	8	0.2759	0.5252	6.307	39.78
Lumbriculus	892.5	9	0.3103	0.5571	6.794	46.16
Aplexa	1,001	10	0.3448	0.5872	6.909	47.73
Thymallus	1,092	11	0.3793	0.6159	6.996	48.94
Pimephales	2,533	12	0.4138	0.6433	7.837	61.42
Oncorhynchus	3,154	13	0.4483	0.6695	8.056	64.91
Salvelinus	4,945	14	0.4828	0.6948	8.506	72.35
Xyrauchen	22,440	15	0.5172	0.7192	10.02	100.4
Gila	22,440	16	0.5517	0.7428	10.02	100.4
Ptychocheilus	22,440	17	0.5862	0.7656	10.02	100.4
Crangonyx	27,600	18	0.6207	0.7878	10.23	104. 6
Tubifex	34,436	19	0.6552	0.8094	10.45	109.1
Cyprinus	36,591	20	0.6897	0.8305	10.51	110.4
Benacus	39,768	21	0.7241	0.8510	10.59	112.2
Lepomis	47,235	22	0.7586	0.8710	10.76	115.8
Chironomus	51,757	23	0.7931	0.8906	10.85	117.8
Oreochromis	55,971	24	0.8276	0.9097	10.93	119.5
Poecilla	78,931	25	0.8621	0.9285	11.28	127.2
Carassius	120,695	26	0.8966	0.9469	11.70	136.9
Tanytarsus	237,815	27	0.9310	0.9649	12.38	153.2
Procambarus	1,589,277	28	0.9655	0.9826	14.28	203.9

[a] GMAV is for Total Lead at a total hardness of 50 mg/L, CMCs at other hardness concentrations are presented in **Table 5** and **Table 15**.

Per the Criteria Guidelines, the FAV recalculation was performed using the four GMAVs which have the cumulative probabilities closest to 0.05 (which in this case are the four lowest GMAVs in **Table 3**) as well as total number of GMAVs (N=28; see **Table 3**). These data and calculations are then used to calculate the FAV. FAV calculations are presented in **Table 4** and **Figure 2**.

Table 4. Four lowest GMAVs for use in Calculating Acute Criterion (CMC) for Total Lead

Genus	GMAV[a] (µg/L)	Rank	P	$\sqrt{P}$	$\ln GMAV$	$(\ln GMAV)^2$
Diaptomus	72.07	1	0.0345	0.1857	4.278	18.30
Gammarus	144.3	2	0.0690	0.2627	4.972	24.72
Ceriodaphnia	147.4	3	0.1034	0.3216	4.993	24.93
Lecane	164.7	4	0.1379	0.3713	5.104	26.05
SUM			**0.3448**	**1.141**	**19.35**	**94.00**

$$S^2 = \frac{\Sigma((\ln GMAV)^2) - ((\Sigma(\ln GMAV))^2/4)}{\Sigma(P) - ((\Sigma(\sqrt{P}))^2/4)} = \frac{94.00 - (19.35^2/4)}{0.3448 - (1.141^2/4)} = 22.10$$

$$S = \sqrt{22.10} = 4.701$$

$$L = (\Sigma(\ln GMAV) - S(\Sigma(\sqrt{P})))/4 = (19.35 - (4.701 * 1.141))/4 = 3.495$$

$$A = S(\sqrt{0.05}) + L = 4.701(\sqrt{0.05}) + 3.495 = 4.546$$

$$FAV = e^{A} = e^{4.545} = 94.25$$

Where:

S = the slope of the geometric mean functional relationship between ln GMAV and sqrt(P). The ln-transformation of the GMAV is used to reduce skewedness and the sqrt(P) is used to provide the best estimate corresponding to P = 0.05.

L = the intercept on the GMAV axis (y axis)

A = the ln-transformed toxicity value corresponding to P = 0.05

Figure 2. Equations used for Calculating the FAV

Per the Criteria Guidelines, the resulting FAV is then used to calculate the CMC as follows:

$$CMC_{\text{Total Lead at a Hardness of 50 mg/L}} = FAV/2 = 94.25/2 = \boxed{\mathbf{47\ \mu g/L}}$$

As enough data are available to show the acute toxicity of two or more species is similarly related to hardness as described earlier in this section, a criteria equation was developed as follows for <u>total lead,</u> per Section V of the Criteria Guidelines:

$$\text{Final Acute Equation}_{\text{Total}} = e^{(\text{pooled slope})*\ln(\text{hardness})+\ln(\text{criterion maximum intercept})}$$

Where:

Pooled Slope = 1.466

$$\ln(\text{criterion maximum intercept}) = \ln(\text{CMC}) - (\text{slope} * \ln(50))$$

$$\text{Final Acute Equation}_{\text{Total}} = e^{1.466*\ln(\text{hardness})-1.882}$$

The CTR criteria are presented as dissolved criteria however, the acute lead toxicity data utilized to calculate the criteria were primarily reported as total recoverable metal. Thus to convert the total lead criteria into dissolved criteria, the CTR (USEPA 2000) conversion factor (CF) for lead is used. The lead CF is hardness dependent, as represented below, and is the same for both acute and chronic lead criteria. An example is shown for a hardness of 50 mg/L.

$$\text{Acute Conversion Factor Lead} = 1.46203 - \ln(\text{hardness}) * 0.145712$$
$$\text{Acute Conversion Factor Lead at 50 hardness} = 1.46203 - \ln(50) * 0.145712$$
$$\text{Acute Conversion Factor Lead at 50 hardness} = 0.892$$

The final acute dissolved criterion equation is as follows:

$$\text{Final Acute Equation}_{\text{Dissolved}} = \text{Acute CF} * \text{Final Acute Equation}_{\text{Total}}$$

Where, from above:

$$\text{Acute Conversion Factor (CF)} = 1.46203 - \ln(\text{hardness}) * 0.145712$$
$$\text{Final Acute Equation}_{\text{Total}} = e^{1.466*\ln(\text{hardness})-1.882}$$

Resulting in:

$$\text{Final Acute Equation}_{\text{Dissolved}} = (1.46203 - \ln(\text{hardness}) * 0.145712) * e^{1.466*\ln(\text{hardness})-1.882}$$

Table 5 presents a summary of the acute total and dissolved lead criteria values for a range of hardness concentrations typically measured in the LA River watershed. Should a site-specific translator be developed for the Los Angeles River watershed, that translator could be applied to the dissolved equation to develop total lead criteria. Data have been collected through the Metals TMDL Coordinated Monitoring Program and may be appropriate for development of a site-specific translator.

Table 5. Summary of Acute Total and Dissolved Lead Water Quality Criterion Values (CMCs) Resulting from Recalculation Using the Approved Dataset

Hardness (mg/L)	CMC (µg/L)	
	Dissolved	Total
50	42	47
100	103	130
200	248	360
300	411	652
400	585	994

3.2 RECALCULATION OF CHRONIC CRITERION

As stated previously, the CTR provides the following equation for the calculation of the dissolved lead CCC, also referred to as the chronic criterion:

$$CCC_{\text{Dissolved Lead}} = \text{WER x (Chronic Conversion Factor) x } (e^{(m_C[\ln(\textit{hardness})]+b_C)})$$

Where:

CCC = Criterion Continuous Concentration for dissolved lead
WER = Water-Effect Ratio equal to 1 in the absence of a site-specific study
Chronic Conversion Factor = 1.46203– ln(hardness)*0.145712
m_C= pooled slope
b_C = final chronic intercept

The recalculation approach can result in an update to each of the factors within the CCC equations except for the WER, which must be based on a site-specific study. The following sections discuss the use of the 2008 USEPA data set in recalculating the CTR chronic criterion.

3.2.1 Updated Chronic Dataset

The 1984 lead criteria document identified seven measured freshwater chronic data points (i.e., chronic values), expressed as the geometric mean of the no observed and lowest observed effect concentrations from an appropriate chronic toxicity test per the Criteria Guidelines. The USEPA-approved updated dataset added seven additional chronic values from seven studies, including data for an additional six species. Acceptable data on the chronic effects of lead to freshwater organisms are available for six invertebrate species (two snails, two cladocerans, an amphipod and a midge) and four fish species. A table presenting the USEPA-approved chronic data, with updates based on those described herein, is located in **Appendix B**. No species were deleted from the chronic dataset to conduct the lead recalculation.

There were, however, a few differences between the data reported in USEPA 2008 and the data utilized herein. Please see Section 3.4 for the discussion of differences.

3.2.2 Updated Chronic Hardness Relationship

Some studies have shown that the reported chronic toxicity values generally increase with increasing hardness levels (e.g., Chapman et al. manuscript), but the overall relationship is relatively weak. There are currently insufficient data to further develop a relationship between hardness and the chronic toxicity of lead. Thus, similar to the CTR lead criteria, the acute pooled slope was utilized for the development of the chronic criterion equation. This was appropriate as the CTR chronic value was derived from the acute toxicity data.

3.2.3 Recalculated Chronic Criterion

Sections VI and VII of the Criteria Guidelines present the approach to determining the final chronic value (FCV) and final chronic equation, respectively. The approach to calculating the FCV is dependent on the available chronic toxicity data. The FCV may be calculated in the same manner as the final acute value (FAV), or, if chronic toxicity data are not available for species of eight families as required by the Criteria Guidelines, by utilizing the Final Acute-to-

Chronic Ratio (FACR).[9] If the chronic toxicity dataset does not meet the minimum data requirements (8 different families) as required by the Criteria Guidelines, the final chronic value must be calculated using the FAV divided by the FACR per the Criteria Guidelines. An Acute-to-Chronic Ratio (ACR) is a way of relating the acute and chronic toxicity of a pollutant to aquatic organisms. ACRs are calculated by dividing the acute toxicity value by the chronic toxicity value for tests conducted on the same species, preferably within the same study. However, allowances are provided if the acute tests were not conducted as part of the same study (see pages 40-41 in the Criteria Guidelines). The ACR represents the ratio of the concentration of a constituent that is acutely toxic to that which results in chronic toxicity. When using the FACR approach to calculate a CCC, the FCV is simply the FAV divided by the FACR. The CCC is then set equal to the FCV (CCC = FCV) as stated in Section XI of the Criteria Guidelines.

The 1984 lead WQC utilized a FACR of 51.29 to calculate an FCV. This FACR was based on the geometric mean of the four available ACRs, since the range of the four values was considered small enough (i.e., within a factor of ten of one another).

The 2008 USEPA-approved dataset was evaluated using section VI of the Criteria Guidelines and it was determined that the ACR method was most appropriate for calculating the CCC, as data were not available from the eight families. ACRs are available for five freshwater species and include at least one fish, one invertebrate and one acutely sensitive species. The Species Mean Acute-Chronic Ratios (SMACRs) range from 4.769 to 61.97, and differ by a factor of approximately 13 times (**Table 6** and **Appendix C**). A review of the data indicates that the SMACRs seem to increase as the SMAV increases, and as recommended by the Criteria Guidelines, when this is the pattern, the SMACRs for species whose SMAVs are closest to the FAV should be used to calculate the FACR. Of the test species for which SMACRs were available, the SMAVs at a hardness value of 50 mg/L for *Ceriodaphnia dubia* (115.4 µg/L) and *Daphnia magna* (160.0 µg/L) were closest. The SMAVs for the other species for which SMACRs were available were significantly higher: *Oncorhynchus mykiss* (719.3 µg/L), *Salvelinus fontinalis* (4,945 µg/L), and *Pimephales promelas* (2,533 µg/L). Thus, the geometric mean of the *Ceriodaphnia dubia* and *Daphnia magna* SMACRs (4.769 and 28.69, respectively – see **Appendix C**) were utilized and yield a freshwater FACR of 11.70.

[9] Acute-chronic ratios (ACRs) are calculated for each set of parallel acute and chronic tests by dividing the acute value by the chronic value. That is, ACR = Acute Value ÷ Chronic Value. At least three species with a specified taxonomic diversity must be addressed by studies with parallel testing to calculate a valid final ratio. An FACR is then the geometric mean of the acute-chronic ratios for each species.

Table 6. Acute and Chronic Data for Calculating SMACRs

Species	Species Mean		
	Acute Value (Total µg/L)	Chronic Value (Total µg/L)	Acute-Chronic Ratio[a]
Brook trout, *Salvelinus fontinalis*	4,100	83.08	49.35
Rainbow trout, *Oncorhynchus mykiss*	1,170	18.88	61.97
Fathead minnow, *Pimephales promelas*	2,100	329.0	6.383
Cladoceran, *Daphnia magna*	517	10.33	28.68[b]
	843	103.9	
	1580	27.19	
Cladoceran, *Ceriodaphnia dubia*	248.0	52.00	4.769

[a] ACR is calculated using acute and chronic values at their test hardness
[b] Geometric mean of the three ACRs

Calculations to determine the FCV (CCC) are provided below at a hardness of 50 mg/L.

FCV = FAV/FACR

FAV = final acute value as determined in ***Section 3.1.3*****, Figure 2**

FACR = *geometric mean of the species ACR* = **11.70**

$CCC_{\text{Total Lead at a Hardness of 50 mg/L}}$ = FCV = 94.25/11.70 = **8.1 µg/L**

Per Section VII of the Criteria Guidelines, the final chronic equation for total lead is as follows:

$\text{Final Chronic Equation}_{\text{Total}} = e^{(\text{pooled slope})*\ln(\text{hardness})+\ln(\text{final chronic intercept})}$

Where:

Pooled Slope = 1.466

ln(final chronic intercept) = ln(FCV) – (slope * ln(50))

$\text{Final Chronic Equation}_{\text{Total}} = e^{1.466*\ln(\text{hardness})-3.649}$

Similar to the CTR lead criteria, the acute pooled slope is utilized in developing the final chronic equation and is appropriate since the chronic value is derived from the acute toxicity data. An example calculation for the chronic WQC is shown below using a hardness of 50 mg/L $CaCO_3$.

Chronic Conversion Factor Lead = 1.46203 – ln(hardness) * 0.145712

Chronic Conversion Factor Lead at 50 hardness = 1.46203 – ln(50) * 0.145712

Chronic Conversion Factor Lead at 50 hardness = 0.892

The final chronic dissolved criterion equation is as follows:

$\text{Final Chronic Equation}_{\text{Dissolved}}$ = Chronic CF * $\text{Final Chronic Equation}_{\text{Total}}$

Where:

Chronic Conversion Factor (CF) = 1.46203 – ln(hardness) * 0.145712

Resulting in:

$$\text{Final Chronic Equation}_{\text{Dissolved}} = (1.46203 - \ln(\text{hardness}) * 0.145712) * e^{1.466*\ln(\text{hardness})-3.649}$$

Table 7 presents a summary of the chronic total and dissolved lead criterion values (CCCs) for a range of hardness concentrations typically measured in the LA River watershed. Should a site-specific translator be developed for the LA River watershed, that translator could be applied to the dissolved equation to develop total lead criteria. Data have been collected through the Metals TMDL Coordinated Monitoring Program and may be appropriate for development of a site-specific translator.

Table 7. Summary of Chronic Total and Dissolved Lead Water Quality Criterion Values (CCCs) Resulting from Recalculation Using the USEPA-Approved Dataset and New FACR

Hardness (mg/L)	CCC (µg/L)	
	Dissolved	Total
50	7.2	8.1
100	18	22
200	42	61
300	70	111
400	100	170

3.3 EVALUATION OF RECALCULATED CRITERIA

Per the Criteria Guidelines (Section IV.A page 26), "in some cases, if the SMAV of a commercially or recreationally important species is lower than the calculated FAV, then the SMAV replaces the calculated FAV in order to provide protection for that important species." Similarly, for the FCV (Section VI.M page 42), "If the Species Mean Chronic Value (SMCV) of a commercially or recreationally important species is lower than the calculated FCV, then that SMCV should be used as the FCV instead of the calculated FCV." Additionally, per the Recalculation Procedure (Section E.3), "The calculated FAV, CMC, and/or CCC must be lowered, if necessary, to (1) protect an aquatic plant, invertebrate, amphibian, or fish species that is a critical species at the Site, and (2) ensure that the criterion is not likely to jeopardize the continued existence of any endangered or threatened species listed under section 4 of the Endangered Species Act or result in the destruction or adverse modification of such species' critical habitat." The following evaluates the recalculated criteria presented in **Section 3.1.3** and **Section 3.2.3** in the context of commercially or recreationally important species as well as species that are listed as threatened or endangered that occur at the "Site," defined as the urbanized areas of the Los Angeles River watershed, and as illustrated in **Figure 1**. There were no commercially or recreationally important species identified at the Site, therefore, **Table 8** presents a list of species that are listed as threatened or endangered, herein referred to as "species of interest." A total of four species of interest were identified. Although there are no data available in the approved lead dataset for these organisms, surrogate species were identified for the species of interest in the approved dataset and the surrogate SMAVs and SMCVs were compared to the FAV and FCV. **Table 9** presents the surrogate species utilized, the corresponding surrogate SMAV and SMCV, and an evaluation of whether the FAV and FCV are greater than or lower than the surrogate SMAV or SMCV. Based on the analysis, none of the surrogate SMAVs or SMCVs for surrogate species representative of the species of interest are lower than the recalculated FAV or FCV. Based on a review of data related to species of interest occurring at the Site, the CMC and CCC presented in **Section 3.1.3** and **Section 3.2.3**, respectively, are protective of species that are listed as threatened or endangered; therefore, recalculated criteria were not adjusted.

Table 8. Species of Interest

Species	Reference of Occurrence	Category
Fish		
Arroyo chub *Gila orcuttii*	CNDDB 2011; ITIS 2008; Moyle 2002; Swift 1993	State Species of Concern
Santa Ana speckled dace *Rhinichthys osculus*	CNDDB 2011; ITIS 2008; Moyle 2002; Swift 1993	State Species of Concern
Santa Ana sucker *Catostomus santaanae*	CNDDB 2011; ITIS 2008; Moyle 2002; Swift 1993; USFWS 2008	Federally-listed Threatened Species; State Species of Concern
Amphibian		
Coast Range newt *Taricha torosa*	CNDDB 2011; ITIS 2008	State Species of Concern

Table 9. A Comparison of Surrogate Species Mean Acute and Chronic Values (SMAVs and SMCVs) of Species Identified for Species of Interest to the Recalculated Final Acute and Chronic Values (FAV and FCV)

Species of Interest	Surrogate Species	Justification	Surrogate SMAV (µg/L)	FAV[1] (µg/L)	SMAV < FAV?	Surrogate SMCV[2] (µg/L)	FCV[1] (µg/L)	SMCV < FCV?
Fish								
Arroyo chub *Gila orcuttii*	Bonytail *Gila elegans*	Same genus (*Gila*)	>22,440[a]	94.25	No	1,918	8.1	No
Santa Ana speckled dace *Rhinichthys osculus*	Colorado squawfish *Ptychocheilus lucius*	Same family (Cyprinidae)	>22,440[a]		No	1,918		No
	Goldfish *Carassius auratus*		120,695[b]		No	10,316		No
	Common carp *Cyprinus carpio*		36,591[c]		No	3,127		No
	Fathead minnow *Pimephales promelas*		2,533[d]		No	397		No
Santa Ana sucker *Catostomus santaanae*	Razorback sucker *Xyrauchen texanus*	Same tribe (Catostomini)	>22,440[a]		No	1,918		No
Amphibian								
Coast Range newt *Taricha torosa*	Marbled salamander *Ambystoma opacum*	Same Order (Caudata)	536.3[e]		No	46		No

[1] Final Acute Value (FAV) and Final Chronic Value (FCV) were calculated based on a hardness of 50 mg/L and compared to the hardness adjusted Species Mean Acute Value (SMAV) at a hardness of 50 mg/L .
[2] SMCV was only available for fathead minnow. Therefore, FCVs/SMCVs were determined for this table based on the FACR value (11.70). For example, SMAV/ACR = SMCV; 22,440/11.70 = 1,918. The actual SMCV for fathead minnow was included in the table. A check was performed using the highest ACR in the dataset (61.97 for rainbow trout), and all SMCVs are higher than the FCV.

References:
a. Buhl 1997, b. Pickering and Henderson 1966, c. Datta and Das 2003, d. Spehar and Fiandt 1986, e. Birge et al. 1978

3.4 COMPARISON TO 2008 AND 1984 CALCULATIONS

The recalculated lead criteria differ from both the 1984 WQC, which are the basis of the CTR, and the criteria calculations presented in USEPA's 2008 *Draft Ambient Aquatic Life Water Quality Criteria for Lead*. **Table 10** presents a final comparison of the 1984, Draft 2008, and recalculated WQC. The following describes the modifications that were made to the 2008 USEPA-approved dataset based on a review and analysis of the data, and provides a discussion on the differences between the 1984 and recalculated WQC.

Table 10. Comparison of 1984, Draft USEPA 2008, and Recalculated Criteria (µg/L)

Hard-ness (mg/L)	1984				Draft USEPA 2008				Recalculation			
	CMC		CCC		CMC		CCC		CMC		CCC	
	Diss	Total	Diss	Total	Diss	Total	Diss	Total	Diss	Total	Diss	Total
50	24	34	0.9	1.3	43	50	9.2	11	42	47	7.2	8.1
100	49	82	1.9	3.2	116	155	25	33	103	130	18	22
200	99	197	3.8	7.7	316	486	68	105	248	360	42	61
300	146	331	5.7	13	567	960	122	206	411	652	70	111
400	191	477	7.4	18	859	1565	185	336	585	994	100	170

CMC = Criterion Maximum Concentration (a.k.a. acute criterion)
CCC = Criterion Continuous Concentration (a.k.a. chronic criterion)

3.4.1 Modifications to 2008 USEPA-approved Dataset

The recalculation presented herein is based on a USEPA-approved dataset presented in USEPA's 2008 *Draft Ambient Aquatic Life Water Quality Criteria for Lead*. However, the recalculated acute and chronic criteria presented in **Sections 3.1.3** and **3.2.3** varies in several ways from the criteria calculations presented in USEPA 2008. The following discusses the differences between the recalculation presented above and USEPA 2008.

The 48-hr (acute) lead LC50s reported in Table 1 of the USEPA's 2008 *Draft Ambient Aquatic Life Water Quality Criteria for Lead* for *D. magna* from the Chapman et al. manuscript (manuscript page 10) and used in the 1984 criteria (USEPA 1985b) were calculated on the basis of initial test concentrations only (612, 952, and 1,910 µg/L total lead at test water hardness levels of 54, 110, and 150 mg/L as $CaCO_3$, respectively). These values were replaced herein with the LC50s (also provided in the manuscript) calculated based on the geometric mean concentration of test treatment water measured at the beginning and ending of the test. These values were reported as 517, 843, and 1,580 µg/L total lead at test water hardness levels of 54, 110, and 150 mg/L as $CaCO_3$, respectively. The values were replaced as it is most common to include the LC50s derived using the mean (arithmetic or geometric) of the measured test concentrations at the beginning and end of an acute test rather than using only the concentration at the beginning of the test, because the mean concentration more closely approximates the true exposure experienced by the test organisms over the duration of the test. This edit resulted in a change to the hardness slope (based on 8 data points) for *D. magna* in the USEPA 2008 dataset from 0.7245 to 0.8415. Replacing the *D. magna* data resulted in a recalculation of the pooled slope to be 1.466 (versus USEPA 2008 pooled slope of 1.442). Changing the pooled slope made it necessary to recalculate the hardness-adjusted SMAVs in **Table 1** of **Appendix A** because the pooled slope is used in the hardness-normalizing equation.

In the Chapman et al. manuscript the maximum acceptable toxicant concentration (MATC) reported as the chronic value for *D. magna* at the test water hardness level of 52 mg/L as $CaCO_3$ (value of 12.26 µg/L total lead) was based on individual fecundity, whereas mean fecundity was used as the chronic endpoint upon which the MATCs at test water hardness levels of 102 and 151 mg/L as $CaCO_3$ were based. The MATC reported for *D. magna* at the test water hardness level of 52 mg/L as $CaCO_3$ was edited in the dataset to use the mean fecundity instead of individual fecundity, in part because mean fecundity was the chronic test effect measure/endpoint used as the basis for the MATC reported for *D. magna* at the water hardness levels of 102 and 151 mg/L as $CaCO_3$ (and so, the MATCs are more consistently represented in the chronic dataset for this test species). Furthermore, mean fecundity takes into account survival of exposed parents (thereby accounting for chronic effects related to mortality <u>and</u> fecundity), whereas individual fecundity does not account for mortality. Additionally, the raw data were used to calculate EC20 values, as this is USEPA's preferred method for calculating chronic endpoints when the appropriate data is available. The 1999 AWQC document for ammonia (USEPA 1999) and the 2007 AWQC document for copper (USEPA 2007) both considered EC20s in determining chronic values. Additionally, the USEPA 1985 Guidelines state "a chronic value may be obtained by calculating the geometric mean of the lower and upper chronic limits from a chronic test or by analyzing chronic data using regression analysis" (such as ECx values). These edits changed the MATCs from 12.26, 119.0, and 128.2 µg/L total lead to EC20s of 10.32, 103.9, and 27.19 µg/L total Pb, which resulted in a different ACRs (particularly at the 151 mg/L hardness level) for *D. magna* than those used in the USEPA 2008 draft criteria, as shown below:

Changes to *Daphnia magna* ACRs

Hardness	2008 ACR	Recalculation ACR
52	49.92	50.05
102	8.013	8.114
151	14.91	58.11
SMACR	18.13	28.68

Lastly, an incorrect LC50 value was presented in the USEPA 2008 updated dataset. The incorrect value was the LC50 value of 1,460 µg/L **total Pb** included for rainbow trout (*Oncorhynchus mykiss*) in the flow-through, measured 96-h test by Goettl et al. (1972), Davies and Everhart (1973), and Davies et al. (1976). It was confirmed by reviewing the original paper that this value presented in the USEPA 2008 draft update dataset for lead was misreported as 1,170 µg/L **dissolved Pb**. Thus, the current value of 1,460 µg/L **total Pb** was replaced with the correct LC50 value for the study of 1,170 µg/L **total Pb**. The SMACR for *O. mykiss* changes from 77.33 back to 61.97, as it was originally reported in 1984. This change had no effect on the recalculation.

Considering the modifications to the USEPA 2008 updated dataset discussed above, the pooled slope contained herein is 1.466 (compared to the USEPA 2008 pooled slope of 1.442) and the updated freshwater FACR is 11.70 (compared to the USEPA 2008 FACR of 9.299).

3.4.2 Comparison to 1984 Water Quality Criteria

The major differences between the 1984 WQC and the recalculated WQC appear to be the result of the increase in data available and subsequent change in regression slope for calculating the 5th percentile value or FAV, and the change in FACR. Sensitive species were also added to the dataset, and the data available for a number of species also increased. For example, the number of GMAVs went from 10 to 28 and three of the four most sensitive species from the 1984 WQC calculations were replaced by more sensitive species.

The overall increase in number of GMAVs and range of effect concentrations across the four most sensitive GMAVs affected the FAV and subsequently the WQC. USEPA defines the FAV as the effect concentration associated with a hypothetical genus that represents the 5th percentile of overall sensitivity (e.g., more sensitive than 95% of all genera based on currently available data). All available GMAVs are included in a sensitivity distribution (SD or SSD), and are ranked in order of sensitivity. Within the sensitivity distribution, each GMAV can be plotted with the y-axis represented by the effect concentration, and the x-axis represented by the percentile of its relative sensitivity, using the equation (P = relative sensitivity rank/(total # of GMAVs +1)). The x-axis value "P" is a function of both the relative ranking of a particular GMAV, as well as the number of total genera. After data are arranged into a SD model, the FAV is calculated by regressing the relationship between the natural log-transformed GMAVs by the square roots of the sensitivity percentiles (P) for the four most sensitive genera, then extending that regression line to the point where P=0.05 (the 5th percentile). The y-axis value associated with the 5th percentile determined by this regression is the FAV.

Almost all of the difference between the recalculated FAV presented herein and the 1984 WQC can be attributed to these two factors: 1) an increase in the number of genera within the dataset; and 2) range of effect concentrations across the four most sensitive GMAVs in this [recalculated] dataset, compared to the 1984 dataset. Both of these factors are discussed in greater detail below.

The dataset used to calculate the FAV in the 1984 WQC consisted of 10 GMAVs. The P-values associated with the four most sensitive genera were 0.09, 0.18, 0.27, and 0.36, respectively, for the most sensitive through the fourth most sensitive genera. For a dataset of this size (10 GMAVs), the FAV will nearly always be lower than the most sensitive genera, because 0.05 (i.e., the probability or P-value associated with the 5th percentile) is lower than 0.09. In contrast, the current updated dataset consists of 28 GMAVs. The P-values associated with the four most sensitive genera were 0.034, 0.069, 0.103, and 0.138, respectively, for the most sensitive through the fourth most sensitive genera. For a dataset of this size, the FAV will nearly always be larger than the most sensitive genera, because 0.05 (i.e., the probability or P-value associated with the 5th percentile) is greater than 0.034.

The second factor influencing the differences in FAVs between the 1984 and current dataset is the spread of effect concentrations associated with the four lowest GMAVs. In 1984 (and when expressed at 50 mg/L total hardness and on the basis of total Pb), the most sensitive genera was *Gammarus* (142.6 µg/L) and the fourth most sensitive genera was *Oncorhynchus* (2,448 µg/L), which was 17.2 times larger than the lowest GMAV. In contrast, the most sensitive genera of the present dataset is *Diaptomus* (72.07 µg/L), and the fourth most sensitive genera was *Lecane*

(164.7 µg/L), which was 2.3 times larger than the lowest GMAV. The more narrow range of effect concentrations among the four lowest GMAVs in the current dataset results in a shallower slope for the regression line developed between the natural log-transformed GMAVs and the square roots of the sensitivity percentiles (P) for the four most sensitive genera, resulting in a higher 5^{th} percentile value than what one would obtain from a steeper slope (wider range of four most sensitive GMAVs) for the same sensitivity percentiles (P).

These two factors, the number of GMAVs in the dataset and the range of effect concentrations across the four most sensitive GMAVs, account for the majority of the difference between the recalculated FAV presented herein and the 1984 WQC FAV, and are far more important than the differences in pooled hardness slopes developed using the two datasets, or to any of the incorrect data values described above.

Figure 3 provides a comparison of the ranked GMAVs normalized to a hardness of 50 mg/L used to calculate the FAV using the 1984 acute lead criteria dataset and the FAV using the recalculated acute lead criteria dataset with GMAVs. Note the relation of the FAVs calculated from the two datasets and where the lowest GMAV falls within the sensitivity distribution. The recalculated FAV lies within the distribution of GMAVs while the 1984 FAV lies well below the lowest GMAV. Therefore, the additional data available for use in the recalculated criteria provide a sufficiently large number of GMAVs for developing the SD that the 5^{th} percentile value is now bracketed within the distribution of the SD. These additional data and extended SD reduce the uncertainty associated with the calculation of the 5^{th} percentile and resulting FAV, compared with the relatively limited data available for use in deriving the 1984 value. Lastly, note in **Figure 3** both the 1984 WQC and the recalculated criteria fall below the lowest GMAV.

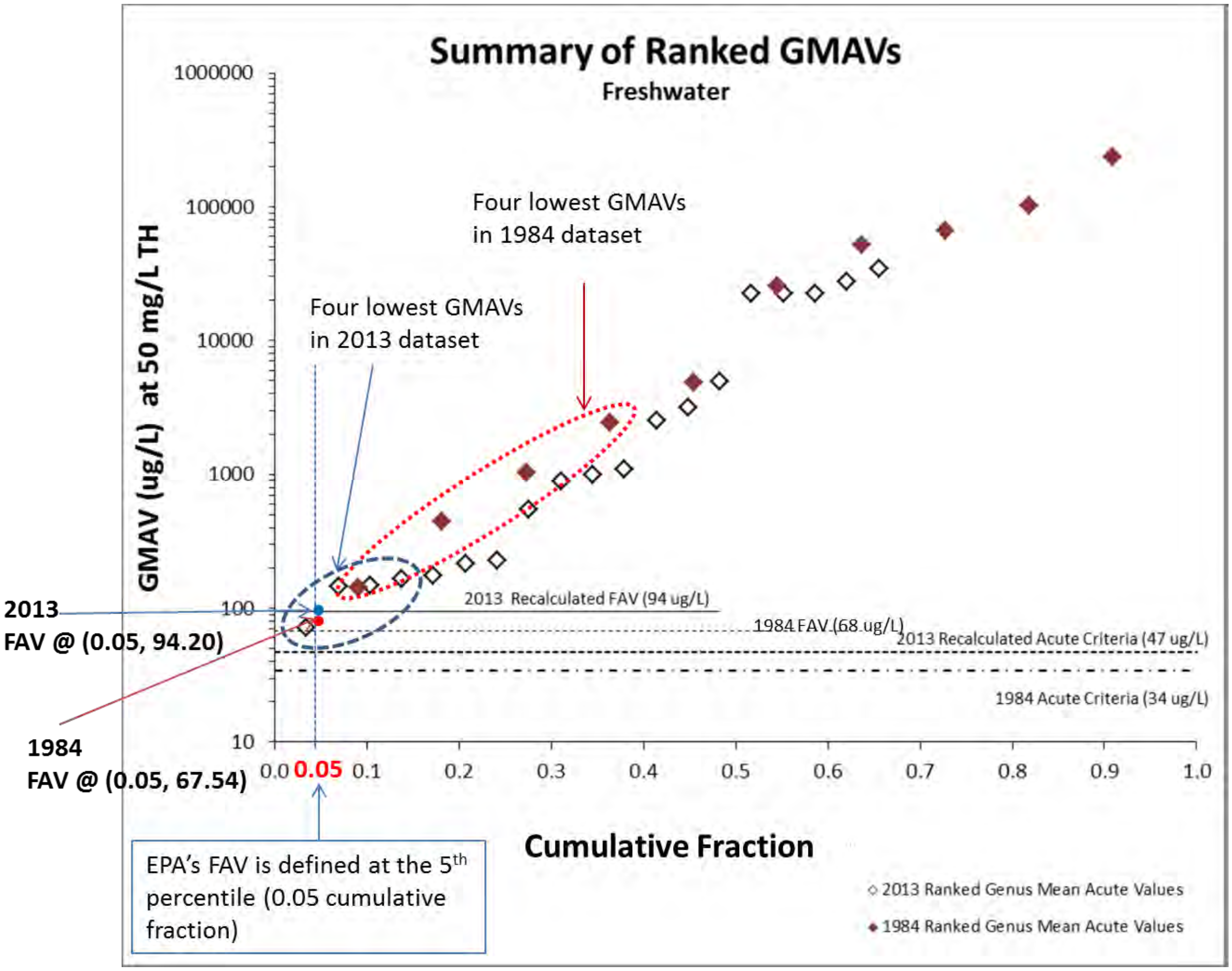

Figure 3. 1984 Lead WQC and Recalculated GMAVs

The 1984 hardness slope (based on 3 data points) for *D. magna* was 1.021. The increase in the pooled slope due to the addition of five *D. magna* data points contributed to the change between the 1984 WQC and the recalculated WQC. **Table 11** presents a comparison of the pooled slope data.

Table 11. Comparison of 1984 and Recalculation Pooled Slopes

1984			Recalculation		
Species	**n**	**Slope**	**Species**	**n**	**Slope**
Daphnia magna	3	1.021	*Daphnia magna*	8	0.8415
			Rainbow trout	5	1.887
Fathead minnow	3	1.495	Fathead minnow	4	1.549
Bluegill	2	1.011	Bluegill	2	1.011
			Carp	5	1.562
All of the above	8	1.273	All of the above	24	1.466

This increase in slope also changed the Acute Values (some increased, some decreased) as the values are normalized to a standard hardness for calculation of the FAV. The change in Acute Values and addition of newer data changed the FAV from 67.54 µg/L (1984 WQC) to 94.25 µg/L (recalculated WQC). The change in Acute Values also had the effect of changing the ACR (1984 = 51.29; recalculation = 11.70) in addition to the increase in available data to calculate the ACR. Lastly, the changes to the FAV and ACR ultimately change the FCV as the FCV is equal to FAV/FACR. **Table 12** presents the effect of various combinations of the 1984 and recalculated FAVs and pooled slopes on the total lead acute WQC[10].

Table 12. Changes in Total Lead Acute WQC (µg/L) due to Changes in FAV and/or Pooled Slope

Hardness (mg/L)	1984 FAV with 1984 slope	1984 FAV with Recalc slope	Recalc FAV with 1984 slope	Recalc FAV with Recalc slope
50	34	34	47	47
100	82	93	114	130
200	197	258	275	360
300	331	467	461	652
400	477	712	665	994

[10] Note that the 1984 slope was used in the final calculations to illustrate relative change, but for this analysis was not used to update the acute values from Appendix A.

Table 13 presents a similar comparison of the effect of changing the ACR on total lead chronic WQC. All of these WQC calculations were done using the recalculated slope (except for the 1984 FAV with 1984 FACR calculations). Additionally, **Table 14** presents a comparison of the effect of changing the pooled slope on total lead chronic WQC.

Table 13. Changes in Total Lead Chronic WQC (µg/L) due to Changes in FACR

Hardness (mg/L)	1984 FAV with 1984 FACR	1984 FAV with Recalc FACR	Recalc FAV with 1984 FACR	Recalc FAV with Recalc FACR
50	1.3	5.8	1.8	8.1
100	3.2	16	5.1	22
200	7.7	44	14	61
300	13	80	25	111
400	19	122	39	170

Table 14. Changes in Total Lead Chronic WQC (µg/L) due to Changes in Pooled Slope

Hardness (mg/L)	1984 FCV with 1984 slope	1984 FCV with Recalc slope	Recalc FCV with 1984 slope	Recalc FCV with Recalc slope
50	1.3	1.3	8.1	8.1
100	3.2	3.6	19	22
200	7.7	10	47	61
300	13	18	79	111
400	19	28	114	170

4 Summary

USEPA methods for the Recalculation Procedure and criteria derivation (via the Criteria Guidelines) were followed to calculate an updated lead FAV and FCV and provide updates to the corresponding criteria equations. By applying the Final Acute and Chronic Equations (presented in **Section 3.1.3** and **Section 3.2.3**, respectively), it is possible to calculate CMC and CCC values at alternative hardness concentrations. Species of interest were identified and based on the available data, the CMC and the CCC are protective. **Table 15** presents examples of CMC and CCC values at varying hardness concentrations similar to those observed in the LA River watershed. The dissolved criteria were converted to total criteria by using the default CTR conversion factor. Should a site-specific translator be developed for the LA River watershed, that translator could be applied to the dissolved equation to develop total lead criteria or TMDL targets. As the entire approved USEPA dataset was utilized, the recalculation of the lead criteria results in a *de facto* recalculation of the national criteria and could be applied to the entire Los Angeles region upon completion of a species of interest analysis in other watersheds, if so desired.

The criteria equations developed herein and presented below may be utilized to adopt site-specific lead objectives for the Los Angeles River and tributaries and/or revise the TMDL targets and allocations. However, this report does not consider the additional requirements for such a regulatory action. Rather, the report presents and documents the calculation of lead criteria consistent with USEPA's Recalculation Procedure.

$$\text{Final Acute Equation}_{\text{Dissolved}} = (1.46203 - \ln(\text{hardness}) * 0.145712) * e^{1.466*\ln(\text{hardness})-1.882}$$

$$\text{Final Chronic Equation}_{\text{Dissolved}} = (1.46203 - \ln(\text{hardness}) * 0.145712) * e^{1.466*\ln(\text{hardness})-3.649}$$

Table 15. Summary of Lead Water Quality Criteria Resulting from Recalculation

Hardness	Acute/CMC (µg/L)		Chronic/CCC (µg/L)	
	Dissolved	Total	Dissolved	Total
50	42	47	7.2	8.1
100	103	130	18	22
200	248	360	42	61
300	411	652	70	111
400	585	994	100	170

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Appendix A

UPDATED WQC Table 1. Acute Toxicity of Lead to Aquatic Animals based on USEPA Ambient Aquatic Life Water Quality Criteria – Lead 2008 Draft

Freshwater Species

Species	Method[a]	Chemical	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (Total µg/L)[b]	LC50 or EC50 (Dissolved µg/L)	LC50 or EC50 Adjusted to TH=50[i] (Total µg/L)	SMAV at TH=50[i] (Total µg/L)[c]	Reference
Rotifer, *Lecane hamata*	S, U	Lead nitrate	135	680	-	**158.5**	158.5	Perez-Legaspi and Rico-Martinez 2001
Rotifer, *Lecane luna*	S, U	Lead nitrate	135	140	-	**32.64**	32.64	Perez-Legaspi and Rico-Martinez 2001
Rotifer, *Lecane quadridentata*	S, U	Lead nitrate	135	3,700	-	**862.6**	862.6	Perez-Legaspi and Rico-Martinez 2001
Worm, *Lumbriculus variegatus*	S, U	-	30	1,800	-	3806.3	-	Bailey and Liu 1980
Worm (adult), *Lumbriculus variegatus*	S, M, T	Lead chloride	290	>8,000	-	>608.0	-	Schubauer-Berigan et al. 1993
Worm, *Lumbriculus variegatus*	F, M, T	-	44	740	-	**892.5**	892.5	Phipps et al. 1995
Worm, *Tubifex tubifex*	S, U	Lead nitrate	237	454,700 (15°C)	-	**46,455**	-	Rathore and Khangarot 2002
Worm, *Tubifex tubifex*	S, U	Lead nitrate	237	514,190 (20°C)	-	**52,533**	-	Rathore and Khangarot 2002
Worm, *Tubifex tubifex*	S, U	Lead nitrate	237	334,140 (25°C)	-	**34,138**	-	Rathore and Khangarot 2002
Worm, *Tubifex tubifex*	S, U	Lead nitrate	237	165,220 (30°C)	-	**16,880**	34,436	Rathore and Khangarot 2002
Snail, *Aplexa hypnorum*	F, M, T	Lead nitrate	61	1,340	-	**1001**	1,001	Call et al. 1981
Cladoceran *Ceriodaphnia dubia* (<24 hr)	R, M, T	Lead nitrate	100	248	-	**89.78**	-	Spehar and Fiandt 1986
Cladoceran, *Ceriodaphnia dubia* (<24 hr),	S, U	Lead chloride	80-100	120	-	**51.53**	-	Bitton et al. 1996
Cladoceran, *Ceriodaphnia dubia* (<24 hr)	R, M, D	Lead nitrate	20-30	30.3	29.1	**86.22**	-	Diamond et al. 1997

Species	Method[a]	Chemical	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (Total µg/L)[b]	LC50 or EC50 (Dissolved µg/L)	LC50 or EC50 Adjusted to TH=50[c] (Total µg/L)	SMAV at TH=50[c] (Total µg/L)[c]	Reference
Cladoceran, *Ceriodaphnia dubia* (<24 hr),	R, M, D	Lead nitrate	20-30	195	187	**554.9**	-	Diamond et al. 1997
Cladoceran, *Ceriodaphnia dubia* (<24 hr),	R, M, D	Lead nitrate	20-30	47.9	46.1	**136.3**	-	Diamond et al. 1997
Cladoceran, *Ceriodaphnia dubia* (<24 hr),	R, M, D	Lead nitrate	20-30	27.5	26.4	**78.25**	115.4	Diamond et al. 1997
Cladoceran, *Ceriodaphnia reticulata* (<24 hr),	S, U	Lead nitrate	240	1,878	-	**188.4**	188.4	Elnabarawy et al. 1986
Cladoceran, *Daphnia galeata*	F, U	Lead nitrate	135	714	-	**166.5**	166.5	Wilson 1980
Cladoceran, *Daphnia magna*	S, U	Lead chloride	-	931	-	-	-	Anderson 1948
Cladoceran, *Daphnia magna*	S, U	Lead nitrate	120	5,000[d]	-	1,386[d]	-	Bringman and Kuhn 1959a,b
Cladoceran, *Daphnia magna*	F, U	Lead nitrate	135	510 (10°C)	-	**118.9**	-	Wilson 1980
Cladoceran, *Daphnia magna*	F, U	Lead nitrate	135	950 (15°C)	-	**221.5**	-	Wilson 1980
Cladoceran, *Daphnia magna*	F, U	Lead nitrate	135	870 (20°C)	-	**202.8**	-	Wilson 1980
Cladoceran, *Daphnia magna*	F, U	Lead nitrate	135	160 (25°C)	-	**37.3**	-	Wilson 1980
Cladoceran, *Daphnia magna*	S, U	Lead nitrate	175	150	-	**23.90**	-	LeBlanc 1982
Cladoceran, *Daphnia magna* (<24 hr),	S, U	Lead nitrate	240	1,815	-	**182.0**	-	Elnabarawy et al. 1986
Cladoceran, *Daphnia magna*	S, U	Lead nitrate	259	3,700	-	**331.9**	-	Ziegenfuss et al. 1986

Species	Method[a]	Chemical	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (Total µg/L)[b]	LC50 or EC50 (Dissolved µg/L)	LC50 or EC50 Adjusted to TH=50[i] (Total µg/L)	SMAV at TH=50[i] (Total µg/L)[c]	Reference
(<24 hr),								
Cladoceran, *Daphnia magna*	S, M, T	Lead nitrate	170	967	-	**160.8**	-	McWilliam and Baird 2002
Cladoceran, *Daphnia magna*	S, M, T	Lead sulfide	-	3,655	-	-	-	Erten-Unal et al. 1998
Cladoceran, *Daphnia magna*	S, U	Lead carbonate	-	>5,000	-	-	-	Erten-Unal et al. 1998
Cladoceran, *Daphnia magna*	S, M, T	Lead chloride	-	3,414	-	-	-	Erten-Unal et al. 1998
Cladoceran, *Daphnia magna*	S, M, T	Lead sulfate	-	3,221	-	-	-	Erten-Unal et al. 1998
Cladoceran, *Daphnia magna*	R, M, T	Lead nitrate	54	517	-	**461.8**	-	Chapman et al. Manuscript
Cladoceran, *Daphnia magna*	R, M, T	Lead nitrate	110	843	-	**265.4**	-	Chapman et al. Manuscript
Cladoceran, *Daphnia magna*	R, M, T	Lead nitrate	152	1,580	-	**309.6**	160	Chapman et al. Manuscript
Cladoceran, *Daphnia pulex*	S, U	Lead nitrate	45	5,100[e]	-	5,952[e]	-	Mount and Norberg 1984
Cladoceran, *Daphnia pulex* (<24 hr),	S, U	Lead nitrate	240	2,003	-	**200.9**	200.9	Elnabarawy et al. 1986
Cladoceran, *Moina macrocopa* (<24 hr),	S, U	Lead nitrate	-	755	-	-	-	Pokethitiyook et al. 1987
Cladoceran, *Simocephalus vetulus*	S, U	Lead nitrate	45	4,500[e]	-	5,252[e]	-	Mount and Norberg 1984
Amphipod, *Crangonyx pseudogracilis*	R, U	Lead nitrate	50	27,600	-	**27,600**	27,600	Martin and Holdich 1986
Amphipod, *Gammarus pseudolimnaeus*	F, M, T	Lead nitrate	46	124	-	**140.1**	-	Spehar et al. 1978
Amphipod, *Gammarus pseudolimnaeus*	F, M, T	Lead nitrate	48	140	-	**148.6**	144.3	Call et al. 1983

Species	Method[a]	Chemical	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (Total µg/L)[b]	LC50 or EC50 (Dissolved µg/L)	LC50 or EC50 Adjusted to TH=50[i] (Total µg/L)	SMAV at TH=50[i] (Total µg/L)[c]	Reference
Amphipod, *Hyalella azteca* (1.2 - 1.3 mm)	F, M, T	-	71	<380[b]	<151	**<227.3**	<227.3	Besser et al. 2005
Copepod (female), *Cyclops bicuspidatus*	F, U	Lead nitrate	135	770 (10°C)	-	**179.5**	-	Wilson 1980
Copepod (female), *Cyclops bicuspidatus*	F, U	Lead nitrate	135	900 (15°C)	-	**209.8**	-	Wilson 1980
Copepod (female), *Cyclops bicuspidatus*	F, U	Lead nitrate	135	1,135 (20°C)	-	**264.6**	215.2	Wilson 1980
Copepod (male), *Diaptomus sicilis*	F, U	Lead nitrate	135	275 (5°C)	-	**64.11**	-	Wilson 1980
Copepod (female), *Diaptomus sicilis*	F, U	Lead nitrate	135	460 (5°C)	-	**107.2**	-	Wilson 1980
Copepod (female), *Diaptomus sicilis*	F, U	Lead nitrate	135	380 (10°C)	-	**88.59**	-	Wilson 1980
Copepod (female), *Diaptomus sicilis*	F, U	Lead nitrate	135	190 (15°C)	-	**44.30**	72.07	Wilson 1980
Crayfish, *Orconectes limsous*	S, M, T	Lead chloride	-	3,300	-	-	-	Boutet and Chaisemartin 1973
Crayfish (adult), *Procambarus clarkii*	S, U	Lead nitrate	-	>400,000	-	-	-	Torreblanca et al. 1987
Crayfish (juvenile), *Procambarus clarkii*	S, M, T	Lead nitrate	30	751,570	-	**1,589,277**	1,589,277	Naqvi and Howell 1993b
Midge (first instar larvae), *Benacus sp*.	S, U	Lead nitrate	5	1,360	-	**39,768**	39,768	Oladimeji and Offem 1989
Midge (first instar larvae), *Chironomus tentans*	S, U	Lead nitrate	5	1,770	-	**51,757**	51,757	Oladimeji and Offem 1989
Midge, *Tanytarsus dissimilis*	F, M, T	Lead nitrate	48	224,000	-	**237,815**	237,815	Call et al. 1983
Coho salmon (alevin), *Oncorhynchus kisutch*	S, U	Lead nitrate	41	7,000	-	**9,364**	-	Buhl and Hamilton 1990

Species	Method[a]	Chemical	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (Total µg/L)[b]	LC50 or EC50 (Dissolved µg/L)	LC50 or EC50 Adjusted to TH=50[i] (Total µg/L)	SMAV at TH=50[i] (Total µg/L)[c]	Reference
Coho salmon (alevin),*Oncorhynchus kisutch*	S, U	Lead nitrate	41	21,700	-	**29,027**	-	Buhl and Hamilton 1990
Coho salmon (0.41 g), *Oncorhynchus kisutch*	S, U	Lead nitrate	41	4,180	-	**5,591**	-	Buhl and Hamilton 1990
Coho salmon (0.94 g), *Oncorhynchus kisutch*	S, U	Lead nitrate	41	>18,000	-	**>24,078**	13,831	Buhl and Hamilton 1990
Rainbow trout (2 mos), *Oncorhynchus mykiss*	F, M, T	Lead nitrate	-	8,000	-	-	-	Hale 1977
Rainbow trout, *Oncorhynchus mykiss*	S, M, T, D	Lead nitrate	385	542,000	1,320	27,190	-	Goettl et al. 1972; Davies and Everhart 1973; Davies et al. 1976
Rainbow trout, *Oncorhynchus mykiss*	S, M, T	Lead nitrate	290	471,000	1,470	35,796	-	Goettl et al. 1972; Davies and Everhart 1973; Davies et al. 1976
Rainbow trout (alevin), *Oncorhynchus mykiss*	S, U	Lead nitrate	41	30,000	-	40,130	-	Buhl and Hamilton 1990
Rainbow trout (0.6 g), *Oncorhynchus mykiss*	S, U	Lead nitrate	41	<1,700	-	<2,274	-	Buhl and Hamilton 1990
Rainbow trout, *Oncorhynchus mykiss*	F, M, T	Lead nitrate	32	1,170[b]	-	**2,251**	-	Goettl et al. 1972; Davies and Everhart 1973; Davies et al. 1976
Rainbow trout, *Oncorhynchus mykiss*	F, M, T	Lead nitrate	140	1,040	1,000	**229.9**	719.3	Rogers et al. 2003
Brook trout, *Salvelinus fontinalis,* (18 mos),	F, M, T	Lead nitrate	44	4,100	-	**4945**	4,945	Holcombe et al. 1976
Arctic grayling (alevin), *Thymallus arcticus*	S, U	Lead nitrate	41	>36,000	-	>48,156[f]	-	Buhl and Hamilton 1990
Arctic grayling (fry), *Thymallus arcticus*	S, U	Lead nitrate	41	12,000	-	16,052[f]	-	Buhl and Hamilton 1990

Species	Method[a]	Chemical	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (Total µg/L)[b]	LC50 or EC50 (Dissolved µg/L)	LC50 or EC50 Adjusted to TH=50[i] (Total µg/L)	SMAV at TH=50[i] (Total µg/L)[c]	Reference
Arctic grayling (0.34 g), *Thymallus arcticus*	S, U	Lead nitrate	41	<320	-	**<428.1**	-	Buhl and Hamilton 1990
Arctic grayling (0.85 g), *Thymallus arcticus*	S, U	Lead nitrate	41	<1,700	-	**<2,274**	-	Buhl and Hamilton 1990
Arctic grayling (0.97 g),*Thymallus arcticus*	S, U	Lead nitrate	41	<1,000	-	**<1,338**	<1,092	Buhl and Hamilton 1990
Goldfish, *Carassius auratus*	S, U	Lead chloride	20	31,500	-	**120,695**	120,695	Pickering and Henderson 1966
Common carp (eggs), *Cyprinus carpio*	F, M, T	Lead nitrate	-	>199	-	-	-	Stouthart et al. 1994
Common carp (fry), *Cyprinus carpio*	S, M, T, D	Lead nitrate	58	8,200	1,350	**6,597**	-	Datta and Das 2003
Common carp (fry), *Cyprinus carpio*	S, M, T, D	Lead nitrate	90	341,000	1,780	**144,054**	-	Datta and Das 2003
Common carp (fry), *Cyprinus carpio*	S, M, T, D	Lead nitrate	170	414,000	1,580	**68,842**	-	Datta and Das 2003
Common carp (fry), *Cyprinus carpio*	S, M, T, D	Lead nitrate	280	554,000	1,400	**44,327**	-	Datta and Das 2003
Common carp (fry), *Cyprinus carpio*	S, M, T, D	Lead nitrate	720	1,129,000	1,470	**22,622**	36,591	Datta and Das 2003
Fathead minnow, *Pimephales promelas*	S, U	Lead chloride	20	5,580	-	21,380	-	Pickering and Henderson 1966
Fathead minnow, *Pimephales promelas*	S, U	Lead chloride	20	7,330	-	28,086	-	Pickering and Henderson 1966
Fathead minnow, *Pimephales promelas*	S, U	Lead chloride	360	482,000	-	26,681	-	Pickering and Henderson 1966
Fathead minnow, *Pimephales promelas* (<24 hr),	S, M, T	Lead chloride	290	>5,400	-	>410.4	-	Schubauer-Berigan et al. 1993
Fathead minnow, *Pimephales promelas*	S, U	Lead sulfide	-	9,958	-	-	-	Erten-Unal et al. 1998

Species	**Method**[a]	**Chemical**	**Hardness (mg/L as $CaCO_3$)**	**LC50 or EC50 (Total µg/L)**[b]	**LC50 or EC50 (Dissolved µg/L)**	**LC50 or EC50 Adjusted to TH=50**[i] **(Total µg/L)**	**SMAV at TH=50**[i] **(Total µg/L)**[c]	**Reference**
Fathead minnow, *Pimephales promelas*	S, U	Lead carbonate	-	>10,000	-	-	-	Erten-Unal et al. 1998
Fathead minnow, *Pimephales promelas*	S, U	Lead chloride	-	167	-	-	-	Erten-Unal et al. 1998
Fathead minnow, *Pimephales promelas*	S, U	Lead sulfate	-	3,166	-	-	-	Erten-Unal et al. 1998
Fathead minnow (30 d), *Pimephales promelas*	F, M, T	Lead nitrate	44	2,100	-	**2,533**	2,533	Spehar and Fiandt 1986
Colorado squawfish (larva and juvenile), *Ptychocheilus lucius*	S, U	Lead nitrate	199	>170,000	-	**>22,440**	>22,440	Buhl 1997
Bonytail (larva and juvenile), *Gila elegans*	S, U	Lead nitrate	199	>170,000	-	**>22,440**	>22,440	Buhl 1997
Razorback sucker (larva and juvenile), *Xyrauchen texanus*	S, U	Lead nitrate	199	>170,000	-	**>22,440**	>22,440	Buhl 1997
Mosquitofish (adult), *Gambusia affinis*	S, U	Lead nitrate	-	240,000[g]	-	-	-	Wallen et al 1957
Mosquitofish, *Gambusia affinis*	S, U	Lead nitrate	-	56,500	-	-	-	Mowbray 1988
Guppy (6 mos), *Poecilla reticulata*	S, U	Lead chloride	20	20,600	-	**78,931**	78,931	Pickering and Henderson 1966
Bluegill, *Lepomis macrochirus*	S, U	Lead chloride	20	23,800	-	**91,192**	-	Pickering and Henderson 1966
Bluegill, *Lepomis macrochirus*	S, U	Lead chloride	360	442,000	-	**24,467**	47,236	Pickering and Henderson 1966
Smallmouth bass (egg and sac fry), *Micropterus dolomieui*	S, M, T	-	152	>15,900	-	>3,115[f]	-	Coughlan et al. 1986
Smallmouth bass (fingerling), *Micropterus dolomieui*	S, M, T	-	152	29,000	-	5,682[f]	-	Coughlan et al. 1986

Species	Method[a]	Chemical	Hardness (mg/L as $CaCO_3$)	LC50 or EC50 (Total µg/L)[b]	LC50 or EC50 (Dissolved µg/L)	LC50 or EC50 Adjusted to TH=50[i] (Total µg/L)	SMAV at TH=50[i] (Total µg/L)[c]	Reference
Smallmouth bass (fry), *Micropterus dolomieui*	S, M, T	-	152	2,800	-	**548.6**	548.6	Coughlan et al. 1986
Tilapia, *Oreochromis hornorum*	S, U	Lead nitrate	120	202,000	-	**55,971**	55,971	Arias et al. 1991
Tilapia, *Oreochromis mossambicus*	R, U	Lead nitrate	-	104,910	-	-	-	James et al. 1996

a S = static; R = renewal; F = flow-through; M = measured; U = unmeasured; T = total metal concentration measured; D=dissolved metal concentration measured.
b Concentration of lead, not the chemical. Where indicated, total lead value was calculated from reported dissolved value and appropriate conversion factor (see text in Section 3.1 Recalculation of Acute Criterion).
c Freshwater Species Mean Acute Values are calculated at a hardness of 50 mg/L using the pooled slope. SMAVs calculated using Lotus spreadsheet, values presented may be different than those calculated with a hand held calculator due to rounding. **Note:** Each SMAV was calculated from the associated bold and underlined number(s) in the preceding column.

d In river water, not used in calculations.

e Not used in calculations because the values in Mount and Norberg (1984) are much higher than values for other species in the same genus or family.

f Not used in calculation because data are available for a more sensitive life stage.

g High turbidity.

h Value not used to calculate the SMAV because the "less than" value is greater than the other value for the species.

i TH=50 denotes total hardness at 50 mg/L as $CaCO_3$

Results of Covariance Analysis of Freshwater Acute Toxicity versus Hardness

Species	n	Slope	Comment	95% Confidence Limits	Degrees of Freedom
Daphnia magna	8	0.8415		-0.8872, 2.5702	6
Rainbow trout	5	1.8868		-1.7323, 5.5059	3
Fathead minnow	4	1.5492		0.1314, 2.9670	2
Bluegill	2	1.0108		(Cannot be calculated)	0
Carp	5	1.5619		-0.1397, 3.2635	3
All of the above	24	1.4658	a	0.8735, 2.0581	18

[a] P = 0. 8988 For equality of slopes

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Appendix B

UPDATED WQC Table 2. Chronic Toxicity of Lead to Aquatic Animals based on USEPA 2008 Ambient Aquatic Life Water Quality Criteria – Lead 2008 Draft
Freshwater Species

Species	Test[a]	Chemical	Hardness (mg/L as $CaCO_3$)	Chronic Limits, Total (ug/L)[b]	Chronic Limits, Dissolved (ug/L)	Chronic Value, Total (ug/L)	Chronic Value, Dissolved (ug/L)	Reference
Snail, *Lymnaea palustris*	LC, T	Lead nitrate	139	12-15	-	25.46	-	Borgmann et al. 1978
Snail, *Lymnaea stagnalis*	LC, D	Lead nitrate	-	13.4-17.9[c]	12-16[c]	15.52	13.86	Grosell et al. 2006
Cladoceran, *Ceriodaphnia dubia*	LC, T	Lead nitrate	100	-	-	52	-	Spehar and Fiandt 1986
Cladoceran, *Ceriodaphnia dubia*	LC, T	-	20	51-99	-	71	-	Jop et al. 1995
Cladoceran, *Daphnia magna*	LC, T	Lead nitrate	52	36.2-102	-	10.33[d]	-	Chapman et al. Manuscript
Cladoceran, *Daphnia magna*	LC, T	Lead nitrate	102	78.2-181	-	103.9[d]	-	Chapman et al. Manuscript
Cladoceran, *Daphnia magna*	LC, T	Lead nitrate	151	85.2-193	-	27.19[d]	-	Chapman et al. Manuscript
Amphipod, *Hyalella azteca*	LC, T	-	136	7.9-18	-	11.92	-	Besser et al. 2005
Midge, *Chironomus tentans*	LC, D	Lead nitrate	-	122-557[c]	109-497[c]	260.7	232.8	Grosell et al. 2006
Rainbow trout, *Oncorhynchus mykiss*	ELS, T	Lead nitrate	28	13.2-27	-	18.88	-	Goettl et al. 1972; Davies and Everhart 1973; Davies et al. 1976
Rainbow trout, *Oncorhynchus mykiss*	ELS, T	Lead nitrate	35	71-146	-	101.8	-	Sauter et al. 1976
Brook trout, *Salvelinus fontinalis*	LC, T	Lead nitrate	44	58-119	-	83.08	-	Holcombe et al. 1976
Fathead minnow, *Pimephales promelas*	ELS, T	Lead nitrate	44	-	-	329	-	Spehar and Fiandt 1986
Smallmouth bass, *Micropterus dolomieui*	LC, T	Lead	152	>405	-	>405	-	Coughlan et al. 1986

[a] LC = life cycle or partial life cycle, ELS = early life stage, T = total metal concentration, D = dissolved metal concentration.
[b] Results are expressed as lead, not as the chemical.
[c] Where indicated, total lead value was calculated from reported dissolved value and appropriate conversion factor.
[d] Results are expressed as the EC20, instead of EC50, using the USEPA TRAP model (Version 1.21A).

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Appendix C

UPDATED WQC Table 3. Ranked Genus Mean Acute Values with Species Mean Acute-Chronic Ratios based on USEPA Ambient Aquatic Life Water Quality Criteria – Lead 2008 Draft Freshwater Species

Rank	Genus Mean Acute Value (Total µg/L)[b]	Species	Species Mean Acute Value (Total µg/L)[b]	Species Mean Acute-Chronic Ratio
28	1,589,277	Crayfish, *Procambarus clarkii*	1,589,277	-
27	237,815	Midge, *Tanytarsus dissimilis*	237,815	-
26	120,695	Goldfish, *Carassius auratus*	120,695	-
25	78,931	Guppy, *Poecilia reticulata*	78,931	-
24	55,971	Tilapia, *Oreochromis homorum*	55,971	-
23	51,757	Midge, *Chironomus tentans*	51,757	-
22	47,236	Bluegill, *Lepomis macrochirus*	47,236	-
20	39,768	Midge, *Benacus sp.*	39,768	-
21	36,591	Common carp, *Cyprinus carpio*	36,591	-
19	34,436	Worm, *Tubifex tubifex*	34,436	-
18	27,600	Amphipod, *Crangonyx pseudogracilis*	27,600	-
17	>22,440	Colorado squawfish, *Ptychocheilus lucius*	>22,440	-
16	>22,440	Bonytail, *Gila elegans*	>22,440	-
15	>22,440	Razorback sucker, *Xyrauchen texanus*	>22,440	-
14	4,945	Brook trout, *Salvelinus fontinalis*	4,945	49.35
13	3,154	Coho salmon, *Oncorhynchus kisutch*	13,831	-
		Rainbow trout, *Oncorhynchus mykiss*	719.3	61.97
12	2,533	Fathead minnow, *Pimephales promelas*	2,533	6.383
11	<1,092	Arctic grayling, *Thymallus arcticus*	<1,092	-

Rank	Genus Mean Acute Value (Total µg/L)[b]	Species	Species Mean Acute Value (Total µg/L)[b]	Species Mean Acute-Chronic Ratio
10	1,001	Snail, *Aplexa hypnorum*	1,001	-
9	892.5	Worm, *Lumbriculus variegatus*	893	-
8	548.6	Smallmouth bass, *Micropterus dolomieui*	548.6	-
7	<227.3	Amphipod, *Hyalella azteca*	<227.3	-
6	215.2	Copepod, *Cyclops bicuspidatus*	215.2	-
5	174.9	Cladoceran, *Daphnia galeata*	166.5	-
		Cladoceran, *Daphnia magna*	160.0	28.69[c]
		Cladoceran, *Daphnia pulex*	200.9	-
4	164.6	Rotifer, *Lecane hamata*	158.5	-
		Rotifer, *Lecane luna*	32.64	-
		Rotifer, *Lecane quadridentata*	862.6	-
3	147.4	Cladoceran, *Ceriodaphnia dubia*	115.4	4.769
		Cladoceran, *Ceriodaphnia reticulata*	188.4	-
2	144.3	Amphipod, *Gammarus pseudolimnaeus*	144.3	-
1	72.07	Copepod, *Diaptomus sicilis*	72.07	-

[a] Ranked from most resistant to most sensitive based on magnitude of GMAV.

[b] Freshwater GMAVs and SMAVs are expressed on the basis of total lead at a hardness of 50 mg/L as $CaCO_3$.

[c] Geometric mean of three values in Table 2 of USEPA-approved 2008 draft WQC document.