

**DEVELOPMENT OF SITE-SPECIFIC
ZINC STANDARDS FOR
WEST FORK CLEAR CREEK
(CLEAR CREEK SEGMENT 5),
CLEAR CREEK COUNTY, COLORADO**

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Prepared for:

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INTRODUCTION

West Fork Clear Creek, Clear Creek Segment 5, was proposed for inclusion on the 2004 State of Colorado 303(d) list as impaired for zinc. This segment has previously had temporary modifications for zinc based on “ambient water quality,” represented by the 85th percentile of sampled concentrations. These temporary modifications for zinc expired in 1996 and existing Table Value Standards (TVS) for acute and chronic zinc concentrations are currently in effect (CDPHE 2002). The underlying standard for Segment 5 West Fork Clear Creek is ~107 µg/L acute and chronic zinc (i.e., the TVS at a mean hardness of ~90 mg/L).

Because of the methods by which current Colorado TVS for acute and chronic zinc toxicity are calculated, the values for acute and chronic are basically equivalent. This is in contrast to other metals where the chronic TVS are typically more restrictive. Furthermore, differences in the manner in which acute and chronic TVS are applied to determine impairment (i.e., acute trigger >1 exceedence over three years or functionally >5% exceedence of individual data points vs. chronic trigger >15% exceedence of individual data points) can result in inclusion on the 303(d) list when potentially impairment does not exist based on classified use attainment.

Consequently, at the request of Climax Molybdenum Company (CMC), Chadwick Ecological Consultants, Inc (CEC) conducted a study of the water quality standards for zinc in relation to the classified uses of West Fork Clear Creek. The classified uses for West Fork Clear Creek are Aquatic Life Cold 1, Recreation 1a and Agriculture (5 CCR 1002-38, Clear Creek, Segment 5). However, “aquatic life” is a broad designation and it is important that the aquatic life expected to be present be characterized (i.e., characterize uses that can be attained), for a specific stream segment to ensure that any proposed standards are protective of that expected “aquatic life” use (Michael and Moore 1997). CEC has evaluated the expected aquatic life uses for Segment 5 West Fork Clear Creek and the appropriate water quality criteria for zinc to protect the expected aquatic life in West Fork Clear Creek.

To determine whether site-specific standards are appropriate, it must be shown that they will be protective of the classified uses. This was accomplished through 1) a review of the results of previous field

sampling of water quality, fish, and benthic invertebrate communities to determine potential resident species in these streams; and 2) use of U.S. EPA methods for recalculation of water quality criteria for metals.

The current version of this report stands as a substantive revision of the previous version. Based on suggestions received from Dave Moon, U.S. EPA Region VIII, and Steve Brinkman, CDOW, the acute and/or chronic zinc toxicity data of several taxa that had been added to the database (from citations in two risk assessment documents provided by U.S. EPA Region VIII: U.S. EPA 2002, 2004) were altered or removed entirely. This resulted in changes in most equations and criteria calculated herein.

RESULTS AND DISCUSSION

Water Quality Characterization

The mean hardness value in West Fork Clear Creek Segment 5 is 91.3 mg/L as CaCO₃, based on routine monitoring data provided recorded by CMC (Appendix A, Table A-1). The median zinc value in the segment was 38.2 µg/L. The 85th percentile zinc value is 83.2 µg/L. The 85th percentile and median zinc values both meet the applicable underlying chronic standard of 107 µg/L in Segment 5. The 95th percentile zinc (a surrogate for use in comparison to acute standards) is 110 µg/L, higher than the acute standard of 107 µg/L.

Potential Resident Fauna

West Fork Clear Creek (Clear Creek Segment 5) between the confluences with Woods Creek (elevation = ~9,900 ft) and Clear Creek (elevation = ~8,500 ft.) is a high altitude, high gradient (~3%) mountain stream. Consequently, several organisms included in the toxicity databases of the zinc criteria may not have “resident” populations in this segment. For example, warmwater fish would not be expected to occur in the segment. Furthermore, based on habitat preferences and known distributions, zooplankton in the family Daphniidae would not be expected to inhabit this stream as resident populations. The potential absence (or presence) of these taxonomic groups can be important, as they often represent sensitive taxa that can drive the final criteria for a particular metal.

Fish Populations

A persistent brook and cutthroat trout population was found in West Fork Clear Creek from 1997-2001 with brook trout dominating in the segment (Aquatic Associates 2002). Trout density averaged ~500 fish/ha and trout biomass averaged ~ 24 kg/ha over the study period. Both small and large size classes were present and while biomass was not particularly high this was likely due to the dominance of shallow riffle habitats, scarcity of pools, and little instream cover. West Fork Clear Creek supports a healthy trout population (Aquatic Associates 2002). Accordingly, trout would be considered potential resident biota and retained in any recalculation of site-specific standards.

Benthic Macroinvertebrates

The benthic macroinvertebrate community of West Fork Clear Creek is typical of western montane streams and representative of a healthy benthic community (Aquatic Associates 2002). Benthic macroinvertebrates are consistently abundant (~2,000-3,500 organisms/m²) and diverse (Shannon-Weaver and EPT diversity indices >3 and >20, respectively). Furthermore, the community is dominated in both the fall and spring by pollution-sensitive insects (i.e., mayflies, stoneflies, and caddisflies). Accordingly, benthic macroinvertebrates in general would be considered resident biota and retained in any recalculation.

However, neither amphipods or isopods would be expected to be resident in mountain streams like the West Fork of Clear Creek.. Amphipods, such as *Hyalella azteca* and *Gammarus lucustris*, have been documented in Colorado, occurring in lentic (i.e., standing water) habitats, specifically associated rooted aquatic macrophytes (i.e., ponds/lakes, below dams, backwater habitats of large, low gradient streams) (Pennak and Rosine 1976). Rooted aquatic macrophytes, which serve as the primary habitat of the amphipods, do not exist in rocky-bottomed, high-gradient Colorado mountain streams (Ward *et al.* 2002). Rather, aquatic macrophytes in these high elevation streams are limited to mosses, lichens and liverworts. The rooted aquatic macrophytes preferred by amphipods and isopods do not become part of the resident flora of Colorado streams until further downstream at lower elevation where the gradient lessens (Ward *et al.* 2002). In fact, with over 5 years of sampling at five sampling sites and thousands of organisms collected, only two amphipods and no

isopods have been collected in the West Fork of Clear Creek (Aquatics Associates, monitoring data). It is apparent that these groups are not resident in the West Fork Clear Creek, Segment 5.

Discussion of Planktonic Microinvertebrates in Lotic Systems

Despite their affinity for lentic habitats, cladocerans are periodically observed in lotic systems. Many of these are “accidentals” washed out of an upstream or off-channel lake, pond, or reservoir, with no means of sustaining a population within the stream system without the contribution of this downstream drift from the source population. Chandler (1937) studied the persistence of plankton drifting from three Michigan lakes into three low gradient, slow flowing rivers. He determined that plankton drifting into the rivers were rapidly eliminated, with Crustacea (which includes cladocerans) and Rotifera being the most quickly removed, having a pronounced decrease in density within a half mile and often within a few meters of the lake. These rates of removal are similar to results reported by Ward (1975), who determined that zooplankton, cladocerans in particular, are fairly rapidly removed from lotic systems below their lentic source. This pattern of cladoceran removal from lotic habitats downstream of lentic “donor” habitats has been well documented (Novotny and Hoyt 1982, Phillips 1995).

Hynes (1970) concluded that zooplankton can maintain themselves against only minimal velocities of a few millimeters/second, and that swiftly flowing systems would quickly eliminate any true zooplankton. Thorp *et al.* (1994) studied the zooplankton community of the Ohio River, and determined that the density of plankton in the river was negatively correlated with river velocity and was probably physically controlled. In a study of the Illinois River and its tributaries in Arkansas, Brown *et al.* (1989) found cladocerans comprised between 0.05 and 10.4% of the total zooplankton density in these streams. The authors note that a negative relationship was observed between plankton density and velocity, specifically when the velocity exceeded 0.05 m/sec. (0.16 ft/sec).

The presence of alpine lakes and beaver ponds within montane aquatic systems may represent a hydrological refuge for crustaceans in streams. Stream sites located between or below beaver ponds may constitute a connection between miniature epilimnetic-release lakes/reservoirs (i.e., beaver ponds). This condition would allow for the perceived “persistence” of the planktonic microinvertebrate populations within a stream through the collection of transients. Beaver ponds have been documented in West Fork Clear Creek

upstream of Segment 5 (Aquatic Associates 2002). However, despite periodic macroinvertebrate sampling with gear that would potentially collect zooplankton within the study segment (i.e., with mesh size of 250 µm), none have been recovered (Tami Schneck, Aquatic Associates, pers. comm.). For comparison, in a study of Mosquito Creek (Park County, Colorado), a stream with roughly similar gradient and flow characteristics to West Fork Clear Creek, CEC documented a transient population of lotic crustaceans at only half the sites sampled, with no microcrustaceans collected at the other sites. When found, cladocerans were quite rare (only found at one site in one season), and copepod populations were highly variable (Table 1) (CEC 2004). Furthermore, when copepods were present they were typically represented by naupliar stages. Nearly identical results were seen by Richardson (1991) in his study of a stream in southern Oklahoma.

TABLE 1: Summary of microinvertebrate population parameters for Mosquito Creek (MC) and South Mosquito Creek (SMC), Colorado, August 2002 and 2003. Each cell represents a 40 L composite sample for 2002 and 2003 (CEC 2004).

Taxa	MC-1	MC-2	MC-3	MC-4	SMC-1	SMC-2
Cladocera	0-0	0-0	0-0	0-2	0-0	0-0
Copepoda	1-47	0-0	0-0	0-55	0-51	0-1

Apparent persistence of transient planktonic microinvertebrates in streams similar to West Fork Clear Creek may also be related to the production of ephippa, or resting egg cases, that are common to cladocerans (Pennak 1989). However, the ephippa of copepods, particularly daphnids (e.g., *Ceriodaphnia* and *Daphnia*) are not adapted to cling or otherwise attach to substrates and would be easily washed downstream in lotic habitats (Vila 1989). This lack of adaptation for a lotic environment further indicates the transient nature of planktonic crustacean populations in swiftly flowing streams and rivers.

Thus, planktonic microinvertebrates would apparently be expected to be present in mountain streams only as transients from upstream or off-channel lentic habitats, such as beaver ponds or alpine lakes. As transients, these organisms would not be able to sustain populations within these streams, which is to be expected given habitat conditions characterized by high gradients and fast velocities with low pool retention times. As transients, planktonic microinvertebrates would not be included in the “expected condition” as resident populations for these streams and, thus, are not included in recalculation of standards for West Fork Clear Creek Segment 5.

POTENTIAL SITE-SPECIFIC ZINC STANDARDS FOR WEST FORK CLEAR CREEK SEGMENT 5

Approaches to Development of Appropriate Zinc Standards

The U.S. EPA has approved three methods to be used in calculating site-specific water quality criteria (U.S. EPA 1994). The first of these is the recalculation procedure. This method is based on modification of the toxicity database upon which the national water quality criteria is based through: 1) addition of species to the database using new data approved by the U.S. EPA; 2) adjustment of existing values for a species already in the database using new, U.S. EPA-approved data; and/or 3) deletion of non-resident species from the database using the results of field studies and literature reviews. The other two methods are the water effects ratio (WER) procedure, and the resident species procedure. This analysis focuses on the first method, recalculation.

The methods for recalculation of metals criteria to reflect site-specific conditions (U.S. EPA 1994, specifically "Appendix B, The Recalculation Procedure"), uses a six-step procedure. The recalculation procedure also states that it is necessary to meet the U.S. EPA's minimum data requirements or MDRs (Stephan *et al.* 1985). These MDRs, which were established for development of national water quality criteria, require a toxicity database containing a minimum of eight families including 1) Salmonidae, 2) another boney fish family (Class Osteichthyes), 3) a third chordate (fish or amphibian), 4) a planktonic crustacean, 5) a benthic crustacean, 6) an insect, 7) a non-arthropod invertebrate family, and 8) a family in another insect order or a phylum not otherwise represented. Using the recalculation guidance, once the potential resident biota of a system has been established, site-specific water quality criteria may be calculated based upon deletion of non-resident species from the database, as detailed below, with methods presented for ensuring that the MDRs are met.

Determination of the Appropriate Resident Fauna

Before beginning a recalculation by deletion of non-resident taxa, one must first determine existing and potential resident fauna. In this case, West Fork Clear Creek provides adequate habitat for benthic macroinvertebrates (minus amphipods and isopods) and salmonid communities. It does not provide adequate

habitat for resident populations of microinvertebrates (zooplankton), although transient populations could be present at times.

Zinc Water Quality Standards

Prior to any recalculation effort through deletion of non-resident fauna from the toxicity database, we conducted a review of the existing criteria, including a literature review for new data. As noted earlier, the current version of this report stands as a substantive revision of the previous version. Based on suggestions received from Dave Moon, U.S. EPA Region VIII, and Steve Brinkman, CDOW, the acute and/or chronic zinc toxicity data of several taxa that had been added to the database (from citations in two bioassessments by U.S. EPA Region VIII: U.S. EPA 2002, 2004) were altered or removed entirely. This resulted in changes in most equations and criteria calculated herein.

Update of National Ambient Zinc Criteria Database

The most recent U.S. EPA-approved zinc toxicity database is presented in the “1995 Updates” (U.S. EPA 1996). This database contains zinc toxicity data for 36 genera representing five phyla. To our knowledge, there are no current U. S. EPA-approved corrections or additions to the database.

We reviewed over 70 papers as potential sources of data to be added to the updated zinc databases, including a number of studies cited by U.S. EPA Region VIII in two documents - the ecological risk assessment of French Gulch (U.S. EPA 2002) and in the development of species sensitivity distribution databases for zinc as part of their Risk Characterization of the Upper Arkansas River in the vicinity of California Gulch (U.S. EPA 2004). Based on this review, over 60 data points from 27 sources were added to the new acute database (Table 2). This increases the acute database to 51 genera. Additionally, we added 22 data points from 11 sources to the updated chronic database (Table 3), which results in the addition of eight new genera (the salmonid *Salmo*, *Cottus*, the mayfly *Ephemera*, an unspecified caddisfly, the caddisfly *Hydropsyche*, two stoneflies, *Acroneuria*, and *Pteronarcys*, and the midge *Tanytarsus*). The updated ranked acute database is summarized in Table 4.

TABLE 2: New acute zinc toxicity data from a review of toxicity literature.

Species	Common Name	Method	Hardnes s	Time (hr.)	LC ₅₀	Adjusted LC ₅₀ *	Reference
<i>Salvelinus fontinalis</i>	Brook trout		60	NR	1,458	1,251	referenced in ERA, U.S. EPA 2002
<i>Salvelinus fontinalis</i>	Brook trout	F, M	52.6	96	738	707	Davies <i>et al.</i> 2000
<i>Salvelinus fontinalis</i>	Brook trout	F, M	52.6	96	1,178	1,129	Davies <i>et al.</i> 2000
<i>Oncorhynchus mykiss</i>	Rainbow trout		60	NR	534	458	referenced in ERA, U.S. EPA 2002
<i>Oncorhynchus mykiss</i>	Rainbow trout	F, M	350	96	4,520	881	Goettl <i>et al.</i> 1972
<i>Oncorhynchus mykiss</i>	Rainbow trout	F, M	350	96	1,190	232	Goettl <i>et al.</i> 1972
<i>Oncorhynchus mykiss</i>	Rainbow trout	F, M	30	96	560	860	Goettl <i>et al.</i> 1972
<i>Oncorhynchus mykiss</i>	Rainbow trout	F, M	30	96	240	369	Goettl <i>et al.</i> 1972
<i>Oncorhynchus mykiss</i>	Rainbow trout	F, M	38	96	105	132	Davies 1980
<i>Oncorhynchus mykiss</i>	Rainbow trout	F, M	38	96	186	234	Davies 1980
<i>Cottus bairdi</i>	Mottled sculpin	F, M	48.6	96	156	160	Woodling <i>et al.</i> 2002
<i>Salmo trutta</i>	Brown trout	F, M	50	96	392	392	Davies and Brinkman 1999
<i>Salmo trutta</i>	Brown trout	F, M	44.7	96	1,033	1,135	Davies and Brinkman 1999
<i>Salmo trutta</i>	Brown trout	F, M	87.3	96	2,267	1,419	Davies and Brinkman 1999
<i>Salmo trutta (wild)</i>	Brown trout (wild)	F, M	39	96	550	678	Davies and Brinkman 1994
<i>Salmo trutta</i>	Brown trout	F, M	42.3	96	476	548	Davies <i>et al.</i> 2000
<i>Salmo trutta</i>	Brown trout	F, M	52.6	96	484	464	Davies <i>et al.</i> 2000
<i>Salmo trutta</i>	Brown trout	F, M	52.6	96	603	578	Davies <i>et al.</i> 2000
<i>Salmo trutta</i>	Brown trout		100	96	1,000	558	Marr 1994
<i>Salmo trutta</i>	Brown trout		50	96	454	454	Marr 1994
<i>Lepomis macrochirus</i>	Bluegill	F, M	NR	96	3,200	3,200	Thompson <i>et al.</i> 1980
<i>Daphnia</i> spp.	Cladoceran		60	NR	282	242	ERA, U.S. EPA 2002
<i>Daphnia magna</i>	Cladoceran	R, M	300	96	1,100	244	Berglund and Dave 1984
<i>Asellus aquaticus</i>	Isopod	S, U	50	96	18,200	18,200	Martin and Holdich 1986
<i>Aeolosoma headleyi</i>	Worm		45	48	18,100	19,776	Cairns <i>et al.</i> 1978
<i>Aeolosoma headleyi</i>	Worm		45	48	17,600	19,229	Cairns <i>et al.</i> 1978
<i>Aeolosoma headleyi</i>	Worm		45	48	15,600	17,044	Cairns <i>et al.</i> 1978
<i>Aeolosoma headleyi</i>	Worm		45	48	15,000	16,389	Cairns <i>et al.</i> 1978
<i>Aeolosoma headleyi</i>	Worm		45	48	13,500	14,750	Cairns <i>et al.</i> 1978
<i>Catostomus latipinnis</i>	Flannelmouth sucker		144	96	1,480	608	Hamilton and Buhl 1997
<i>Chironomus</i> sp.	Midge		50	96	18,200	18,200	Rehwooldt <i>et al.</i> 1973
<i>Cypris</i> sp.	Ostracod		114	48	3,000	1,501	Qureshi <i>et al.</i> 1980a
<i>Dugesia tigrina</i>	Flatworm		50	96	7,400	7,400	See <i>et al.</i> 1974
<i>Dugesia tigrina</i>	Flatworm		40	96	5,480	6,610	See 1976
<i>Echinogammarus tibaldii</i>	Amphipod		240	96	25,900	6,931	Pantani <i>et al.</i> 1997
<i>Gammarus italicus</i>	Amphipod		240	96	8,800	2,355	Pantani <i>et al.</i> 1997
<i>Heliodiaptomus viduus</i>	Copepod		37.6	48	500	635	Sharma and Selverai 1994
<i>Hyaella azteca</i>	Amphipod		100	96	436	244	Eisenhauer <i>et al.</i> 1999
<i>Mesocyclops hyalinus</i>	Copepod		37.6	96	3,800	4,828	Sharma and Selverai 1994
<i>Moina irrasa</i>	Cladoceran		5	48	77.46	536	Zou and Bu 1994
<i>Moina irrasa</i>	Cladoceran		5	48	152.51	1,056	Zou and Bu 1994
<i>Moina irrasa</i>	Cladoceran		5	48	205.31	1,422	Zou and Bu 1994
<i>Moina irrasa</i>	Cladoceran		5	48	49.99	346	Zou and Bu 1994

TABLE 2: Continued.

Species	Common Name	Method	Hardnes s	Time (hr.)	LC ₅₀	Adjusted LC ₅₀ *	Reference
<i>Moina irrasa</i>	Cladoceran		5	48	92.88	643	Zou and Bu 1994
<i>Moina irrasa</i>	Cladoceran		5	48	59.24	410	Zou and Bu 1994
<i>Moina macrocopa</i>	Cladoceran		37.6	48	120	152	Sharma and Selverai 1994
<i>Ranatra elongata</i>	Water scorpion		112.4	96	1,658	839	Shukla <i>et al.</i> 1983
<i>Stenocypris malcomsoni</i>	Ostracod		37.6	96	3,500	4,447	Sharma and Selverai 1994
Trichoptera	Caddisfly		50	96	58,100	58,100	Rehwoldt <i>et al.</i> 1973
<i>Tubifex tubifex</i>	Worm		224	48	130,000	36,865	Qureshi <i>et al.</i> 1980b
<i>Tubifex tubifex</i>	Worm		34.2	96	2,570	3,536	Brkovic-Popovic & Popovic 1977
<i>Tubifex tubifex</i>	Worm		261	96	60,200	15,013	Brkovic-Popovic & Popovic 1977
<i>Tubifex tubifex</i>	Worm		0.1	96	110	20,399	Brkovic-Popovic & Popovic 1977
<i>Tubifex tubifex</i>	Worm		34.2	96	2,980	4,100	Brkovic-Popovic & Popovic 1977
Zygoptera	Damselfly		50	96	26,200	26,200	Rehwoldt <i>et al.</i> 1973

* Adjusted LC₅₀ determined using revised slope (0.8404) from Table 5.

TABLE 3: Updated chronic zinc database, with new data denoted by *.

Species	Common Name	Hardness	Chronic Value	New Data	Reference
<i>Daphnia magna</i>	Cladoceran	45	<140.3		Biesinger <i>et al.</i> 1986
<i>Daphnia magna</i>	Cladoceran	52	135.8		Chapman <i>et al.</i> Manuscript
<i>Daphnia magna</i>	Cladoceran	104	47.29		Chapman <i>et al.</i> Manuscript
<i>Daphnia magna</i>	Cladoceran	211	46.73		Chapman <i>et al.</i> Manuscript
<i>Daphnia</i> spp.	Cladoceran	60	59	*	referenced in ERA, U.S. EPA 2002
<i>Clistoronia magnifica</i>	Caddisfly	31	>5,243		Nebeker <i>et al.</i> 1984
Trichoptera	Caddisfly	60	9,046	*	referenced in ERA, U.S. EPA 2002
<i>Hydropsyche betteni</i>	Caddisfly	52	32,000	*	Warnick and Bell 1969
<i>Ephemerella grandis</i>	Mayfly	30-70	>9,200	*	Nehring 1976
<i>Ephemerella subvaria</i>	Mayfly	54	16,000	*	Warnick and Bell 1969
<i>Acroneuria lycorias</i>	Stonefly	50	32,000	*	Warnick and Bell 1969
<i>Pteronarcys californica</i>	Stonefly	30-70	>13,900	*	Nehring 1976
<i>Tanytarsus</i> spp.	Midge	46.8	36.8	*	Anderson <i>et al.</i> 1980
<i>Oncorhynchus nerka</i>	Sockeye salmon	32-37	>242		Chapman 1978a
<i>Oncorhynchus tshawytscha</i>	Chinook salmon	25	371.1		Chapman 1975
<i>Oncorhynchus mykiss</i>	Rainbow trout	26	276.7		Sinley <i>et al.</i> 1974
<i>Oncorhynchus mykiss</i>	Rainbow trout	25	603		Cairns <i>et al.</i> 1982
<i>Oncorhynchus mykiss</i>	Rainbow trout	60	825	*	referenced in ERA, U.S. EPA 2002
<i>Salvelinus fontinalis</i>	Brook trout	45.9	854.7		Holcombe <i>et al.</i> 1979
<i>Salvelinus fontinalis</i>	Brook trout	60	1,049	*	referenced in ERA, U.S. EPA 2002
<i>Salvelinus fontinalis</i>	Brook trout	52.6	327	*	Davies <i>et al.</i> 2000
<i>Salvelinus fontinalis</i>	Brook trout	52.6	819	*	Davies <i>et al.</i> 2000
<i>Salmo trutta</i>	Brown trout	39	457	*	Davies and Brinkman 1994
<i>Salmo trutta</i>	Brown trout	52.6	234	*	Davies <i>et al.</i> 2000
<i>Salmo trutta</i>	Brown trout	52.6	327	*	Davies <i>et al.</i> 2000
<i>Salmo trutta</i>	Brown trout	22-35	640	*	Nehring and Goettl 1974
<i>Salmo trutta</i>	Brown trout	26.8	162	*	Davies and Brinkman 1999, 2002, 2003
<i>Salmo trutta</i>	Brown trout	48.1	196	*	Davies and Brinkman 1999, 2002, 2003
<i>Salmo trutta</i>	Brown trout	54.1	381	*	Davies and Brinkman 1999, 2002, 2003
<i>Salmo trutta</i>	Brown trout	153	1,306	*	Davies and Brinkman 1999, 2002, 2003
<i>Oncorhynchus clarki</i>	Cutthroat trout	34-47	670	*	Nehring and Goettl 1974
<i>Pimephales promelas</i>	Fathead minnow	46	106.3		Benoit and Holcombe 1978
<i>Cottus bairdi</i>	Mottled sculpin	46.3	20.8	*	Woodling <i>et al.</i> 2002
<i>Jordanella floridae</i>	Flagfish	44	36.41		Spehar 1976a,b
<i>Poecilia reticulata</i>	Guppy	30	<173		Pierson 1981

TABLE 4: Updated acute zinc GMAV and SMAV ranked from least sensitive to most sensitive (all modified by revised slope = 0.8404).

Rank	Species	Common Name	GMAV	SMAV	Code
51	<i>Argia</i> sp.	Damselfly	88,403.7	88,403.7	1, 2
50	Trichoptera	Caddisfly	58,100.0	58,100.0	1,2
49	Zygoptera	Damselfly	26,200.0	26,200.0	2
48	<i>Crangonyx pseudogracilis</i>	Amphipod	19,800.0	19,800.0	1, 2
47	<i>Xenopus laevis</i>	Frog	19,267.9	19,267.9	2
46	<i>Nais</i> sp.	Worm	18,400.0	18,400.0	1, 2
45	<i>Chironomus</i> sp.	Midge	18,200.0	18,200.0	1, 2
44	<i>Fundulus diaphanus</i>	Banded killifish	17,953.1	17,953.1	2
43	<i>Aeolosoma headleyi</i>	Worm	17,338.2	17,338.2	1, 2
42	<i>Amnicola</i> sp.	Snail	16,816.7	16,816.7	1, 2
41	<i>Anguilla rostrata</i>	American eel	13,593.8	13,593.8	2
40	<i>Tubifex tubifex</i>	Worm	11,036.1	11,036.1	1, 2
39	<i>Asellus bicrenata</i>	Isopod	10,689.2	5,756.8	1, 2
	<i>Asellus aquaticus</i>	Isopod		18,200.0	1, 2
	<i>Asellus communis</i>	Isopod		11,596.6	1, 2
38	<i>Lepomis gibbosus</i>	Pumpkinseed	10,560.1	18,796.9	2
	<i>Lepomis macrochirus</i>	Bluegill		5,932.6	2
37	<i>Carassius auratus</i>	Goldfish	10,213.8	10,213.8	2
36	<i>Lumbriculus variegatus</i>	Worm	9,677.9	9,677.9	1, 2
35	<i>Cyprinus carpio</i>	Common carp	7,219.1	7,219.1	2
34	<i>Dugesia tigrina</i>	Flatworm	6,994.0	6,994.0	1, 2
33	<i>Echinogammarus tibaldii</i>	Amphipod	6,930.8	6,930.8	1, 2
32	<i>Ptychocheilus oregonensis</i>	Northern squawfish	6,545.7	6,545.7	2
31	<i>Poecilia reticulata</i>	Guppy	6,040.0	6,040.0	2
30	<i>Notemigonus crysoleucus</i>	Golden shiner	6,000.0	6,000.0	2
29	<i>Corbicula fluminea</i>	Asiatic clam	4,908.4	4,908.4	1, 2
28	<i>Mesocyclops hyalinus</i>	Copepod	4,828.5	4,828.5	1, 2
27	<i>Stenocypris malcomsoni</i>	Ostracod	4,447.3	4,447.3	1, 2
26	<i>Xiphophorus maculatus</i>	Southern platyfish	4,377.4	4,377.4	2
25	<i>Gammarus</i> sp.	Amphipod	4,367.5	8,100.0	1, 2
	<i>Gammarus italicus</i>	Amphipod		2,354.9	1, 2
24	<i>Pimephales promelas</i>	Fathead minnow	3,357.3	3,357.3	2
23	<i>Lirceus alabamiae</i>	Isopod	3,289.9	3,289.9	1, 2
22	<i>Catostomus commersoni</i>	White sucker	1,777.2	5,191.7	2
	<i>Catostomus latipinnis</i>	Flannelmouth sucker		608.4	2
21	<i>Salvelinus fontinalis</i>	Brook trout	1,644.2	1,644.2	1
20	<i>Lophopodella carteri</i>	Bryozoan	1,723.5	1,723.5	1, 2
19	<i>Jordanella floridae</i>	Flagfish	1,670.1	1,670.1	2
18	<i>Plumatella emarginata</i>	Bryozoan	1,622.5	1,622.5	1, 2
17	<i>Helisoma campanulatum</i>	Snail	1,577.1	1,577.1	1, 2
16	<i>Cypris</i> sp.	Ostracod	1,500.8	1,500.8	1, 2
15	<i>Physa gyrina</i>	Snail	1,351.9	1,679.1	1, 2
	<i>Physa heterostropha</i>	Snail		1,088.5	1, 2

TABLE 4: Continued.

Rank	Species	Common Name	GMAV	SMAV	Code
14	<i>Pectinatella magnifica</i>	Bryozoan	1,319.4	1,319.4	1, 2
13	<i>Limnodrilus hoffmeisteri</i>	Worm	1,270.0	1,270.0	1, 2
12	<i>Salmo salar</i>	Atlantic salmon	1,156.1	2,157.0	1
	<i>Salmo trutta</i>	Brown trout		619.7	1
11	<i>Oncorhynchus mykiss</i>	Rainbow trout	909.9	638.2	1
	<i>Onchorhynchus kisutch</i>	Coho salmon		1,620.4	1
	<i>Oncorhynchus nerka</i>	Sockeye salmon		1,493.2	1
	<i>Oncorhynchus tshawytscha</i>	Chinook salmon		443.9	1
10	<i>Ranatra elongata</i>	Water scorpion	839.3	839.3	1, 2
9	<i>Tilapia mossambica</i>	Mozambique tilapia	794.6	794.6	2
8	<i>Heliodiaptomus viduus</i>	Copepod	635.3	635.3	1, 2
7	<i>Moina irrasa</i>	Cladoceran	314.0	647.3	1, 2
	<i>Moina macrocopa</i>	Cladoceran		152.5	
6	<i>Daphnia magna</i>	Cladoceran	279.7	357.9	1, 2
	<i>Daphnia pulex</i>	Cladoceran		252.7	1, 2
	<i>Daphnia</i> spp.	Cladoceran		241.9	1, 2
5	<i>Hyaella azteca</i>	Amphipod	243.5	243.5	1, 2
4	<i>Agrosia chrysogaster</i>	Longfin dace	230.1	230.1	2
3	<i>Cottus bairdi</i>	Mottled sculpin	159.8	159.8	2
2	<i>Morone saxatilis</i>	Striped bass	120.1	120.1	2
1	<i>Ceriodaphnia dubia</i>	Cladoceran	93.9	174.2	1, 2
	<i>Ceriodaphnia reticulata</i>	Cladoceran		50.7	1, 2

1- cold water species

2- warm water species

Using all data included in the “1995 Updates,” as well as new data obtained from our literature review, we also developed an updated acute hardness slope, following the guidance for the determination of an acute slope described by Stephan *et al.* (1985). The process involves the natural log transformation of the hardness and acute toxicity values for each species in which acute values exist for a wide range of hardness values. Hardness slopes for each species are calculated as the slope from a least squares regression of the transformed acute values on the corresponding transformed hardness values. If covariance analysis shows these individual slopes are similar, the pooled acute slope is subsequently determined by treating all data as if they were from the same species and conducting a least squares regression of all the ln-transformed values on the corresponding transformed hardness values (Stephan *et al.* 1985). Using the data obtained from our literature review combined with the original data from the criteria documents, an updated acute hardness slope was determined (0.8404) using the same approach from the most recent zinc criteria documents (Table 5). The

updated slope was used to adjust acute values to a hardness of 50 mg/L for recalculation and is also used in the hardness-based final acute equation.

TABLE 5: Acute pooled hardness slope recalculation for acute zinc.

	LC ₅₀	ln LC ₅₀	hardness	ln hard
<u>New Toxicity vs Hardness Data</u>				
<i>Salmo trutta</i>	1,033	6.9402	54	3.9890
	2,267	7.7262	206	5.3279
	454	6.1181	50	3.9120
	1,000	6.9078	100	4.6052
			slope =	0.8700
<i>Oncorhynchus mykiss</i>	560	6.3279	30	3.4012
	240	5.4806	30	3.4012
	4,520	8.4163	350	5.8579
	1,190	7.0817	350	5.8579
	534	6.2804	60	4.0943
	105	4.6540	38	3.6376
	186	5.2257	38	3.6376
			slope =	0.9498
<i>Salvelinus fontinalis</i>	1,458	7.2848	60	4.0943
	738	6.6039	52.6	3.9627
	1,178	7.0716	52.6	3.9627
			slope =	3.3964
<u>Updated Acute Slope Information</u>				
Species		n	slope	
<i>Physa heterostropha</i>		12	0.9296	
<i>Daphnia magna</i>		7	1.2549	
Rainbow trout (updated with new data)		32	0.8558	
Brook trout (updated with new data)		9	1.0613	
Brown trout (new data)		4	0.8700	
Fathead minnow		36	0.8310	
Guppy		5	1.6441	
Striped bass		2	0.6500	
Bluegill		16	0.5603	
		123	0.8404	new slope

An updated acute-chronic ratio was also determined using all data reported in the current criteria document and data obtained from CEC’s literature review (Table 6). Methods followed those described by Stephan *et al.* (1985). Seven new data points were added from studies in which acute and chronic values were calculated at similar hardness values for a given species. Using the current ratio (2.000), the acute and chronic standards are the same value, since the final acute value is divided by two before the intercept for the final acute equation is determined. However, the updated acute-chronic ratio (2.8906) yields chronic values that are lower than acute values (a more realistic scenario).

TABLE 6: Derivation of revised acute-to-chronic ratio for zinc.

Existing ACR data:		New ACR derivation data using data below:	
Species	Ratio	Species	Ratio
<i>Oncorhynchus mykiss</i>	1.554	<i>Daphnia magna</i>	7.2601
<i>Oncorhynchus tshawytscha</i>	0.7027	<i>Daphnia</i> spp.	4.7797
<i>Daphnia magna</i>	7.26	<i>Oncorhynchus mykiss</i>	1.5540
<i>Pimephales promelas</i> *	5.664	<i>Oncorhynchus tshawytscha</i>	0.7027
<i>Salvelinus fontinalis</i> *	2.335	<i>Salvelinus fontinalis</i>	1.8016
<i>Jordanella floridae</i> **	41.2	<i>Salmo trutta</i>	1.6809
U.S. EPA acute-chronic ratio =	1.993973	<i>Cottus bairdi</i>	7.5000
		<i>Pimephales promelas</i>	5.6640
		Revised acute-chronic ratio =	2.8906

New ACR data from updated toxicity databases:					
Species	Hardness	Acute Value	Chronic Value	Ratio	Reference
<i>Salvelinus fontinalis</i>	60	1,458.0	1,049.0	1.3988	referenced in ERA, U.S. EPA 2002
<i>Salvelinus fontinalis</i>	52.6	932.4	517.5	1.8017	Davies <i>et al.</i> 2000
<i>Cottus bairdi</i>	46.3-48.6	156.0	20.8	7.5000	Woodling <i>et al.</i> 2002
<i>Salmo trutta</i>	50	392.0	194.0	2.0206	Davies and Brinkman 1999
<i>Salmo trutta</i>	39	550.0	457.0	1.2035	Davies and Brinkman 1994
<i>Salmo trutta</i>	52.6	540.2	276.6	1.9530	Davies <i>et al.</i> 2000
<i>Daphnia</i> spp.	60	282.0	59.0	4.7797	referenced in ERA, U.S. EPA 2002

* not used in U.S. EPA calculation, but used with this update.

** not used because order of magnitude different.

The updated zinc criteria are then calculated using the genus mean acute values for the four most sensitive genera (*Agrosia*, *Cottus*, *Morone*, and *Ceriodaphnia*). From these values, a final acute value of 152.7 µg/L was calculated resulting in an updated and revised final acute equation of $e^{0.8404 [\ln(\text{hardness})] + 1.0480}$. Using the new acute-chronic ratio, the resulting updated and revised chronic equation would be $e^{0.8404 [\ln(\text{hardness})] + 0.6796}$. Table 7 presents a summary of these updated and revised basic zinc standards at varying hardness levels.

TABLE 7: Summary of existing and revised zinc standards at varying hardness levels using updated toxicity database, revised pooled hardness-slope, and updated acute-to-chronic ratio.

Equations	Mean Hardness in mg/L CaCO ₃									
	25	50	75	100	150	200	250	300	350	400
Current Standards										
Acute = $e^{0.8473 [\ln (\text{hardness})] + 0.08618}$	32.20	65.13	91.84	117.19	165.23	210.83	254.71	297.26	338.70	379.32
Chronic = $e^{0.8473 [\ln (\text{hardness})] + 0.8669}$	36.50	65.66	92.58	118.14	166.57	212.55	256.78	299.68	341.49	382.40
Updated/Revised Standards										
Acute = $e^{0.8404 [\ln (\text{hardness})] + 1.0480}$	42.65	76.38	107.38	136.75	192.28	244.86	295.37	344.28	391.90	438.44
Chronic = $e^{0.8404 [\ln (\text{hardness})] + 0.6796}$	29.51	52.84	74.29	94.61	133.03	169.41	204.35	238.19	271.13	303.33

Site-Specific Zinc Standard for West Fork Clear Creek (Clear Creek Segment 5)

A site-specific zinc criteria was developed for West Fork Clear Creek using U.S. EPA methods (U.S. EPA 1994). The first step was to determine if all species in the updated acute database must be retained or deleted based on their status as warm or coldwater biota. Warmwater fish were deleted. Second, the genus *Cottus*, although a coldwater fish, was excluded from the updated database because the Family Scorpaeniformes does not occur in Colorado east of the Continental Divide (Woodling 1985). Additionally, amphipods and isopods were not included as they are not resident in West Fork Clear Creek. Cladocerans were deleted from the updated database because of their transient nature in lotic systems and probable non-resident status in West Fork Clear Creek. Finally, this recalculation also includes a modification of the toxicity data for the genus *Oncorhynchus* and *Salmo* following a suggestion of representatives from the CDOW and with agreement by the WQCD and U.S. EPA Region VIII. This involves the exclusion of non-resident salmon data (e.g., coho, sockeye, and chinook) from the recalculated genus mean acute value (GMAV) for *Oncorhynchus* and *Salmo*.

Following the determination of appropriate deletions, the remaining data constitute the site-specific database for recalculation for this stream. The deletion of non-resident biota from the updated database resulted in a site-specific database of 22 genera representing roughly 16 families (Table 8).

TABLE 8: Revised site-specific acute zinc SMAVs for West Fork Clear Creek, Segment 5.

Rank	Species	Common Name	GMAV	SMAV
22	Trichoptera	Caddisfly	58,100.0	58,100.0
21	<i>Nais</i> sp.	Worm	18,400.0	18,400.0
20	<i>Chironomus</i> sp.	Midge	18,200.0	18,200.0
19	<i>Aeolosoma headleyi</i>	Worm	17,338.2	17,338.2
18	<i>Ammicola</i> sp.	Snail	16,819.7	16,816.7
17	<i>Tubifex tubifex</i>	Worm	11,036.1	11,036.1
16	<i>Lumbriculus variegatus</i>	Worm	9,677.9	9,677.9
15	<i>Dugesia tigrina</i>	Flatworm	6,994.0	6,994.0
14	<i>Catostomus commersoni</i>	White sucker	5,191.7	5,191.7
13	<i>Corbicula fluminea</i>	Asiatic clam	4,908.4	4,908.4
12	<i>Stenocypris malcomsoni</i>	Ostracod	4,447.3	4,447.3
11	<i>Salvelinus fontinalis</i>	Brook trout	1,664.2	1,644.2
10	<i>Lophopodella carteri</i>	Bryozoan	1,723.5	1,723.5
9	<i>Plumatella emarginata</i>	Bryozoan	1,622.5	1,622.5
8	<i>Helisoma campanulatum</i>	Snail	1,577.1	1,577.1
7	<i>Cypris</i> sp.	Ostracod	1,500.8	1,500.8
6	<i>Physa gyrina</i>	Snail	1,351.9	1,679.1
	<i>Physa heterostropha</i>	Snail		1,088.5
5	<i>Pectinatella magnifica</i>	Bryozoan	1,319.4	1,319.4
4	<i>Limnodrilus hoffmeisteri</i>	Worm	1,270.0	1,270.0
3	<i>Ranatra elongata</i>	Water scorpion	839.3	839.3
2	<i>Oncorhynchus mykiss</i>	Rainbow trout	638.2	638.2
1	<i>Salmo trutta</i>	Brown trout	619.7	619.7

Subsequently, the site-specific hardness-based equation would be calculated as summarized in Table 9. The resulting acute criteria for dissolved zinc is $e^{0.8404 [\ln (\text{hardness})] + 2.3523}$. Using this equation and mean site-specific hardness values of 90 mg/L as CaCO₃, the site-specific acute dissolved zinc standard is 461.25 µg/L. Using the new acute-chronic ratio, the site specific equation used to determine the hardness-based chronic criteria for dissolved zinc would be $e^{0.8404 [\ln (\text{hardness})] + 1.9840}$. Again, based upon a mean hardness value of 90 mg/L as CaCO₃, the site-specific dissolved chronic zinc standard would be 319.14µg/L. When adjusted to two significant digits (U.S. EPA practice) the site-specific standards become 460 µg/L acute and 320 µg/L chronic.

TABLE 9: Recalculation of the final acute and chronic values for zinc with potential non-resident taxa removed (N = 22 genera, R = sensitivity rank in database, P = rank ÷ N+1).

Rank	Genus	GMAV (µg/L)	ln GMAV	(ln GMAV) ²	P = R/(N+1)	√P
4	<i>Limnodrilus</i>	1,270.0	7.1468	51.0794	0.1739	0.4170
3	<i>Ranatra</i>	839.3	6.7326	45.3275	0.1304	0.3612
2	<i>Oncorhynchus</i>	638.2	6.4587	41.7142	0.0870	0.2949
1	<i>Salmo</i>	619.7	6.4292	41.3351	0.0435	0.2085
Sum of columns			26.7672	179.4531	0.4348	1.2856

Calculations:

Acute Criterion

$$S^2 = \frac{\sum (\ln \text{GMAV})^2 - (\sum \ln \text{GMAV})^2 / 4}{\sum P - (\sum \sqrt{P})^2 / 4} = \frac{179.0194 - (26.7350)^2 / 4}{0.4348 - (1.2816)^2 / 4} = 13.7357 \quad S = 3.7062$$

$$L = [\sum \ln \text{GMAV} - S(\sum \sqrt{P})] / 4 = [26.7350 - 3.7062(1.2816)] / 4 = 5.5044$$

$$A = S(\sqrt{0.05}) + L = (3.7062)(0.2236) + 5.5044 = 6.3331$$

$$\text{Final Acute Value} = \text{FAV} = e^A = 562.8930 \quad \text{CMC} = \frac{1}{2} \text{FAV} = 281.4465$$

$$\text{Pooled Slope} = 0.8404$$

$$\begin{aligned} \ln(\text{Criterion Maximum Intercept}) &= \ln \text{CMC} - [\text{pooled slope} \times \ln(\text{standardized hardness level})] \\ &= \ln(281.4465) - [0.8404 \times \ln(50)] \\ &= 2.3523 \end{aligned}$$

$$\text{Recalculated Acute Zinc Criterion} = e^{0.8404 [\ln(\text{hardness})] + 2.3523} \quad @ \text{ Hardness } 90 = 461.25 \mu\text{g/L}$$

Chronic Criterion

$$\text{Assumed Chronic Slope} = 0.8404$$

$$\text{Final Acute-to-Chronic ratio (FACR)} = 2.8906 \text{ (recalculated)}$$

$$\text{Final Chronic Value (FCV)} = \text{FAV} \div \text{ACR} = 562.8930 \div 2.8906 = 194.7322$$

$$\begin{aligned} \ln(\text{Final Chronic Intercept}) &= \ln \text{FCV} - [\text{chronic slope} \times \ln(\text{standardized hardness level})] \\ &= \ln(194.7322) - [0.8404 \times \ln(50)] \\ &= 1.9840 \end{aligned}$$

$$\text{Recalculated Chronic Zinc Criterion} = e^{0.8404 [\ln(\text{hardness})] + 1.9840} \quad @ \text{ Hardness } 90 = 319.14 \mu\text{g/L}$$

SUMMARY AND RECOMMENDATIONS

In general, aquatic habitat in Segment 5 West Fork Clear Creek appears to be sufficient to support fish and macroinvertebrate populations. Flows are variable throughout the year, reflecting typical mountain stream hydrology, with high peak snowmelt flows in the spring and low baseflows throughout the winter. Existing habitat does not appear suitable for supporting resident microinvertebrate, amphipod, or isopod populations in this segment. This conclusion is supported by periodic field sampling in West Fork Clear Creek from 1997-2001 that recovered no microinvertebrates, amphipods, or isopods. Subsequent to these reviews, the U.S. EPA protocols for recalculation of Ambient Water Quality Criteria for metals were used to determine the appropriate site-specific water quality criteria for zinc.

Based on the analysis presented above and the U.S. EPA protocols for determination of water quality criteria, site-specific zinc acute and chronic criteria were developed for West Fork Clear Creek, Segment 5 (Table 10). The site-specific final equation for acute is $e^{0.8404[\ln(\text{hard})]+2.3523}$, and for chronic it is $e^{0.8404[\ln(\text{hard})]+1.9840}$.

TABLE 10: Summary of existing and recommended site-specific water quality criteria for zinc for West Fork Clear Creek, Segment 5. All zinc values are as dissolved ($\mu\text{g/L}$). WQS are based on segment mean hardness of 90 mg/l.

Standard	Hardness (mg/L as CaCO_3)	85 th Percentile Value	95 th Percentile Value	Current Table Value Standards	Recommend Site- Specific Standard
Acute	90	--	110	107	460
Chronic	90	83.2	--	107	320

We recommend the adoption of these site-specific zinc standards for West Fork Clear Creek (Clear Creek Segment 5). These criteria are expected to provide sufficient protection for the expected aquatic communities and better reflect the criteria necessary for potential resident biota.

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APPENDIX A
WATER QUALITY DATA

TABLE A-1: Zinc ($\mu\text{mg/l}$) and hardness (mg/l) data from 5 monitoring sites along West Fork Clear Creek, Clear Creek Segment 5. Date Sources: CC-15 and CC-20 = Upper Clear Creek Watershed Association; U-1 = Climax Molybdenum Company; 131 = Colorado Water Control District; 39 = Colorado Department of Wildlife. Highlighted zinc concentrations indicate dates where Acute Zn TVS Water Quality Standards (WQS) were exceeded.

Site ID	Date	Zinc	Hardness	Zn Acute WQS
CC 15	2/9/1998	85.3		
CC 15	4/7/1998	87.1	162.0	177.3
CC 15	5/21/1998	189.0	65.2	82.0
CC 15	6/17/1998	39.3	38.5	52.5
CC 15	7/13/1998	20.6	26.9	38.7
CC 15	8/18/1998	27.5	49.8	65.2
CC 15	10/14/1998	53.4	89.6	107.3
CC 15	2/8/1999	96.7	165.0	180.0
CC 15	4/7/1999	75.7	154.0	169.8
CC 15	5/12/1999	110.0	130.0	147.1
CC 15	6/17/1999	77.0	35.0	48.4
CC 15	7/12/1999	30.0	35.0	48.4
CC 15	8/17/1999	40.0	62.0	78.6
CC 15	10/13/1999	58.0	130.0	147.1
CC 15	12/9/1999	84.8	179.0	192.9
CC 15	2/7/2000	83.2	175.0	189.2
CC 15	4/4/2000	89.6	176.0	190.2
CC 15	5/17/2000	105.2	46.1	61.1
CC 15	6/15/2000	29.2	28.4	40.5
CC 15	7/17/2000	32.0	46.7	61.8
CC 15	8/22/2000	38.9	86.3	104.0
CC 15	10/11/2000	43.5	120.0	137.5
CC 15	12/7/2000	83.7	155.0	170.7
CC 15	2/5/2001	89.1	185.0	198.4
CC 15	4/3/2001	64.0	169.0	183.7
CC 15	5/9/2001	106.0	96.7	114.5
CC 15	6/14/2001	38.1	28.7	40.9
CC 15	7/16/2001	33.7	43.1	57.7
CC 15	8/21/2001	38.2	101.0	118.8
CC 15	10/10/2001	36.5	154.0	169.8
CC 15	12/6/2001	52.6	177.0	191.1
CC 15	2/4/2002	61.4	222.0	231.5
CC 15	4/2/2002	51.9	180.0	193.8
CC 15	5/23/2002	31.4	58.2	74.5
CC 15	6/12/2002	22.8	39.0	53.0
CC 15	7/15/2002	21.8	67.5	84.4
CC 15	8/13/2002	22.2	92.2	110.0
CC 15	10/16/2002	44.9	60.9	77.4
CC 15	12/5/2002	43.2	184.1	197.5
CC 15	2/3/2003	36.1	155.0	170.7

TABLE A-1: Continued.

Site ID	Date	Zinc	Hardness	Zn Acute WQS
CC 15	4/1/2003	113.0	191.0	203.8
CC 15	5/15/2003	268.8	119.0	136.5
CC15	6/11/2003	78.5	38.5	52.5
CC 15	7/14/2003	30.8	44.8	59.7
CC 15	8/12/2003	33.9	80.2	97.7
CC 15	10/8/2003	45.5	105.0	122.8
CC 20	2/9/1998	34.9		
CC 20	4/7/1998	37.9	103.0	120.8
CC 20	5/21/1998	77.8	49.1	64.5
CC 20	6/17/1998	21.5	31.7	44.5
CC 20	7/13/1998	20.0	25.0	36.4
CC 20	8/18/1998	17.3	38.3	52.2
CC 20	10/14/1998	31.9	61.3	77.8
CC 20	12/10/1998	43.0	90.2	107.9
CC 20	2/8/1999	47.7	98.0	115.8
CC 20	4/7/1999	38.6	100.0	117.8
CC 20	5/12/1999	59.0	98.0	115.8
CC 20	6/17/1999	37.0	32.0	44.9
CC 20	7/12/1999	19.0	30.0	42.5
CC 20	8/17/1999	120.0	44.0	58.7
CC 20	10/13/1999	38.0	79.0	96.5
CC 20	12/9/1999	50.0	101.0	118.8
CC 20	2/7/2000	45.1	102.0	119.8
CC 20	4/4/2000	47.9	106.0	123.7
CC 20	5/17/2000	51.5	41.8	56.2
CC 20	6/15/2000	18.1	28.0	40.1
CC 20	7/17/2000	20.5	40.3	54.5
CC 20	8/22/2000	23.8	60.5	76.9
CC 20	10/11/2000	29.1	77.0	94.4
CC 20	12/7/2000	44.3	95.2	113.0
CC 20	2/5/2001	44.3	114.0	131.6
CC 20	4/3/2001	36.8	109.0	126.7
CC 20	5/9/2001	53.0	85.4	103.0
CC 20	6/14/2001	22.3	25.8	37.4
CC 20	7/16/2001	18.3	33.9	47.1
CC 20	8/21/2001	20.6	60.8	77.3
CC 20	10/10/2001	23.8	87.6	105.3
CC 20	12/6/2001	26.8	99.4	117.2
CC 20	2/4/2002	31.1	124.0	141.3
CC 20	4/2/2002	14.0	95.4	113.2
CC 20	5/23/2002	21.9	52.1	67.8
CC 20	6/12/2002	15.4	39.8	54.0
CC 20	7/15/2002	12.5	58.9	75.2

TABLE A-1: Continued.

Site ID	Date	Zinc	Hardness	Zn Acute WQS
CC 20	8/13/2002	13.1	71.2	88.3
CC 20	10/16/2002	30.2	92.1	109.9
CC 20	12/5/2002	20.5	103.9	121.7
CC 20	2/3/2003	21.4	91.3	109.0
CC 20	4/1/2003	27.7	123.0	140.4
CC 20	5/15/2003	49.3	85.8	103.5
CC 20	6/11/2003	43.2	32.8	45.8
CC 20	7/14/2003	19.8	34.4	47.7
CC 20	8/12/2003	18.2	51.8	67.5
CC 20	10/8/2003	21.4	67.6	84.5
U-1	1/7/1998	110.0	188.0	201.1
U-1	1/13/1999	20.0	29.0	41.3
U-1	11/3/1999	70.0	156.0	171.7
U-1	1/13/2000	100.0	202.0	213.7
U-1	1/3/2001	77.0	172.0	186.5
U-1	1/2/2002	76.0	198.0	210.1
U-1	7/3/2002	20.0	52.8	68.6
U-1	10/3/2002	37.0	110.0	127.7
U-1	6/20/2003	40.0	29.0	41.3
U-1	10/22/2003	80.0	140.0	156.6
131	3/5/1998	37.0	95.0	112.8
131	9/16/1998	29.0	53.0	68.8
131	11/17/1998	35.0	60.0	76.4
131	12/22/1998	69.0	88.0	105.7
131	3/2/1999	860.0	99.0	116.8
131	4/24/1999	43.0	95.0	112.8
39	8/28/1998	17.0	50.0	65.5
39	9/22/1998	20.0	86.0	103.7
39	3/20/1999	45.0	112.0	129.7
39	11/13/1999	34.0	86.0	103.7
39	1/25/2000	34.0	108.0	125.7
Mean =		55.7	91.3	109.1
n =		114.0		
85th percentile =		83.2		
median =		38.2		

Denotes exceedence of acute WQS.

Note: All UCCWA data (CC-15 and CC-20) for period of record was used to provide spacial comparison. Climax (U-1), WQCD (131) and DOW (39) data added unless sampling occurred within 1 week of existing UCCWA sample.