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

APRIL 2004

CEC

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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 (WQCC 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.

RESULTS AND DISCUSSION

Water Quality Characterization

The mean hardness value in West Fork Clear Creek Segment 5 is 91.3 mg/L as $CaCO_3$, 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 segement. 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/m^2) 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. 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, 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 like 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.

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 the development of species sensitivity distribution databases (USEPA 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 53 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 *Ephemerella*, 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	Hardness	Time	LC_{50}	Adjusted LC_{50}	Reference
Salvelinus fontinalis	Brook trout		60	NR	1,458	1,248	referenced in ERA, USEPA 2002
Salvelinus fontinalis	Brook trout		47	96-hr	1,550	1,634	Holcombe & Andrew 1978
Salvelinus fontinalis	Brook trout		44	96-hr	2,420	2,699	Holcombe & Andrew 1978
Salvelinus fontinalis	Brook trout		179	96-hr	6,980	2,351	Holcombe & Andrew 1978
Salvelinus fontinalis	Brook trout	F, M	52.6	96-hr	738	707	Davies *et al*. 2000
Salvelinus fontinalis	Brook trout	F, M	52.6	96-hr	1,178	1,128	Davies *et al*. 2000
Oncorhynchus mykiss	Rainbow trout		60	NR	1,004	859	referenced in ERA, USEPA 2002
Oncorhynchus mykiss	Rainbow trout		60	NR	936	801	referenced in ERA, USEPA 2002
Oncorhynchus mykiss	Rainbow trout		60	NR	534	457	referenced in ERA, USEPA 2002
Oncorhynchus mykiss	Rainbow trout	F, M	22	96-hr	815	1,642	Chapman 1978
Oncorhynchus mykiss	Rainbow trout	F, M	22	96-hr	93	187	Chapman 1978
Oncorhynchus mykiss	Rainbow trout	F, M	22	96-hr	136	274	Chapman 1978
Oncorhynchus mykiss	Rainbow trout	F, M	83	96-hr	1,760	1,142	Chapman & Stevens 1978
Oncorhynchus mykiss	Rainbow trout	F, M	350	96-hr	4,520	859	Goettl *et al*. 1972
Oncorhynchus mykiss	Rainbow trout	F, M	350	96-hr	1,190	226	Goettl *et al*. 1972
Oncorhynchus mykiss	Rainbow trout	F, M	30	96-hr	560	866	Goettl *et al*. 1972
Oncorhynchus mykiss	Rainbow trout	F, M	30	96-hr	240	371	Goettl *et al*. 1972
Oncorhynchus mykiss	Rainbow trout		47	96-hr	370	390	Holcombe & Andrew 1978
Oncorhynchus mykiss	Rainbow trout		178	96-hr	2,510	849	Holcombe & Andrew 1978
Oncorhynchus mykiss	Rainbow trout	F, M	25	96-hr	430	777	Sinley *et al*. 1975
Oncorhynchus mykiss	Rainbow trout	F, M	330	96-hr	7210	1,441	Sinley *et al*. 1975
Oncorhynchus mykiss	Rainbow trout	F, M	38	96-hr	105	133	Davies 1980
Oncorhynchus mykiss	Rainbow trout	F, M	38	96-hr	186	235	Davies 1980
Cottus bairdi	Mottled sculpin	F, M	48.6	96-hr	156	160	Woodling *et al*. 2002
Salmo trutta	Brown trout	F, M	50	96-hr	392	392	Davies and Brinkman 1999
Salmo trutta	Brown trout	F, M	44.7	96-hr	1,033	1,137	Davies and Brinkman 1999
Salmo trutta	Brown trout	F, M	86.6	96-hr	690	432	Davies and Brinkman 1999
Salmo trutta	Brown trout	F, M	87.3	96-hr	2,267	1,409	Davies and Brinkman 1999
Salmo trutta (wild)	Brown trout (wild)	F, M	39	96-hr	1,250	1,545	Davies and Brinkman 1994(a)
Salmo trutta (wild)	Brown trout (wild)	F, M	39	96-hr	550	680	Davies and Brinkman 1994(a)
Salmo trutta	Brown trout	F, M	42.3	96-hr	476	549	Davies *et al*. 2000
Salmo trutta	Brown trout	F, M	52.6	96-hr	484	464	Davies *et al*. 2000
Salmo trutta	Brown trout	F, M	52.6	96-hr	603	577	Davies *et al*. 2000
Salmo trutta	Brown trout		100	96-hr	1,000	554	Marr 1994
Salmo trutta	Brown trout		50	96-hr	454	454	Marr 1994
Lepomis machrochirus	Bluegill	F, M	NR	96-hr	3,200	3,200	Thompson *et al*. 1980
Chironomidae	Midge		60	NR	12,306	10,533	ERA, USEPA 2002
Daphnia	Cladoceran		60	NR	128	110	ERA, USEPA 2002
Daphnia magna	Cladoceran	R, M	300	96-hr	1,100	238	Berglind and Dave 1984
Asellus aquaticus	Isopod	S, U	50	96-hr	18,200	18,200	Martin and Holdich 1986
Aeolosoma headleyi	Worm		45	48-hr.	18100	19803	Cairns *et al*. 1978
Aeolosoma headleyi	Worm		45	48-hr.	17600	19256	Cairns *et al*. 1978
Aeolosoma headleyi	Worm		45	48-hr.	15600	17068	Cairns *et al*. 1978

TABLE 2: Continued.

Species	Common Name	Method	Hardness	Time	LC_{50}	Adjusted LC_{50}	Reference
Aeolosoma headleyi	Worm		45	48-hr.	15000	16411	Cairns *et al*. 1978
Aeolosoma headleyi	Worm		45	48-hr.	13500	14770	Cairns *et al*. 1978
Catostomus latipinnis	Flannelmouth Sucker		144	96	1480	600	Hamilton and Buhl 1997
Chironomus sp.	Midge		50	96	18200	18200	Rehwoldt *et al*. 1973
Cypris sp.	Ostracod		114	48	3000	1485	Qureshi *et al*. 1980a
Dugesia tigrina	Flatworm		50	96	7400	7400	See *et al*. 1994
Dugesia tigrina	Flatworm		40	96	5480	6629	See 1976
Echinogammarus tibaldii	Amphipod		240	96	25900	6792	Pantani *et al*. 1997
Gammarus italicus	Amphipod		240	96	8800	2308	Pantani *et al*. 1997
Haplodiaptomus viduus	Copepod		37.6	48	500	638	Sharma and Selverai 1994
Hyalella azteca	Amphipod		100	96	436	241	Eisenhauer *et al*. 1999
Mesocyclops hyalinus	Copepod		37.6	96	3800	4846	Sharma and Selverai 1994
Moina irrasa	Cladoceran		5	48	77.46	553	Zou and Bu 1994
Moina irrasa	Cladoceran		5	48	152.51	1088	Zou and Bu 1994
Moina irrasa	Cladoceran		5	48	205.31	1465	Zou and Bu 1994
Moina irrasa	Cladoceran		5	48	49.99	357	Zou and Bu 1994
Moina irrasa	Cladoceran		5	48	92.88	663	Zou and Bu 1994
Moina irrasa	Cladoceran		5	48	59.24	423	Zou and Bu 1994
Moina macrocopa	Cladoceran		37.6	48	120	153	Sharma and Selverai 1994
Ranatra elongata	Water scorpion		112.4	96	1658	831	Shukla *et al*. 1983
Stenocypris malcomsoni	Ostracod		37.6	96	3500	4464	Sharma and Selverai 1994
Trichoptera	Caddisfly		50	96	58100	58100	Rehwoldt *et al*. 1973
Tubifex tubifex	Worm		224	96	130000	36158	Qureshi *et al*. 1980b
Tubifex tubifex	Worm		34.2	96	2570	3554	Brkovic-Popovic & Popovic 1977
Tubifex tubifex	Worm		261	96	60200	14696	Brkovic-Popovic & Popovic 1977
Tubifex tubifex	Worm		0.1	96	110	22102	Brkovic-Popovic & Popovic 1977
Tubifex tubifex	Worm		34.2	96	2980	4121	Brkovic-Popovic & Popovic 1977
Zygoptera	Damselfly		50	96	26200	26200	Rehwoldt *et al*. 1973

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

Species	Common Name	Hardness	Chronic Value	New Data	Reference
Daphnia magna	Cladoceran	45	<140.3		Biesinger *et al*. 1986
Daphnia magna	Cladoceran	52	135.8		Chapman *et al*. Manuscript
Daphnia magna	Cladoceran	104	47.29		Chapman *et al*. Manuscript
Daphnia magna	Cladoceran	211	46.73		Chapman *et al*. Manuscript
Daphnia spp.	Cladoceran	60	118	*	ERA, USEPA 2002
Clistoronia magnifica	Caddisfly	31	>5,243		Nebeker *et al*. 1984
Caddisfly	Caddisfly	60	18,092	*	ERA, USEPA 2002
Hydropsyche betteni	Caddisfly	52	32,000	*	Warnick and Bell 1969
Ephemerella grandis	Mayfly	30-70	>9,200	*	Nehring 1976
Ephemerella subvaria	Mayfly	54	16,000	*	Warnick and Bell 1969
Acroneuria lycorias	Stonefly	50	32,000	*	Warnick and Bell 1969
Pteronarcys californica	Stonefly	30-70	>13,900	*	Nehring 1976
Tanytarsus spp.	Midge	46.8	36.8	*	Anderson *et al*. 1980
Oncorhynchus nerka	Sockeye salmon	32-37	>242		Chapman 1978a
Oncorhynchus tshawytscha	Chinook salmon	25	371.1		Chapman 1975
Oncorhynchus mykiss	Rainbow trout	26	276.7		Sinley *et al*. 1974
Oncorhynchus mykiss	Rainbow trout	25	603		Cairns *et al*. 1982
Oncorhynchus mykiss	Rainbow trout	60	1,650	*	referenced in ERA, USEPA 2002
Salvelinus fontinalis	Brook trout	45.9	854.7		Holcombe *et al*. 1979
Salvelinus fontinalis	Brook trout	60	2,098	*	referenced in ERA, USEPA 2002
Salvelinus fontinalis	Brook trout	52.6	327	*	Davies *et al*. 2000
Salvelinus fontinalis	Brook trout	52.6	819	*	Davies *et al*. 2000
Salmo trutta	Brown trout	39	457	*	Davies and Brinkman 1994a
Salmo trutta	Brown trout	52.6	234	*	Davies *et al*. 2000
Salmo trutta	Brown trout	52.6	327	*	Davies *et al*. 2000
Salmo trutta	Brown trout	22-35	640	*	Nehring and Goettl 1974
Salmo trutta	Brown trout	26.8	162	*	Davies and Brinkman 1999, 2002, 2003
Salmo trutta	Brown trout	48.1	196	*	Davies and Brinkman 1999, 2002, 2003
Salmo trutta	Brown trout	54.1	381	*	Davies and Brinkman 1999, 2002, 2003
Salmo trutta	Brown trout	153	1,306	*	Davies and Brinkman 1999, 2002, 2003
Oncorhynchus clarki	Cutthroat trout	34-47	670	*	Nehring and Goettl 1974
Pimephales promelas	Fathead minnow	46	106.3		Benoit and Holcombe 1978
Cottus bairdi	Mottled sculpin	46.3	20.8	*	Woodling *et al*. 2002
Jordanella floridae	Flagfish	44	36.41		Spehar 1976a,b
Poecilia reticulata	Guppy	30	<173		Pierson 1981

TABLE 4: Updated acute zinc GMAV and SMAV ranked from least sensitive to most sensitive (top 12 modified for slope).

Rank	Species	Common Name	GMAV	SMAV	Code
53	*Argia* sp.	Damselfly	88,960.0	88,960.0	1, 2
52	Trichoptera	Caddisfly	58,100.0	58,100.0	1,2
51	Zygoptera	Damselfly	26,200.0	26,200.0	2
50	*Crangonyx pseudogracilis*	Amphipod	19,800.0	19,800.0	1, 2
49	*Xenopus laevis*	Frog	19,176.0	19,176.0	2
48	*Nais* sp.	Worm	18,400.0	18,400.0	1, 2
47	*Chironomus sp.*	Midge	18,200.0	18,200.0	1, 2
46	*Fundulus diaphanus*	Banded killifish	17,940.0	17,940.0	2
45	*Aeolosoma headleyi*	Worm	17,361.7	17,361.7	1, 2
44	*Amnicola* sp.	Snail	16,820.0	16,820.0	1, 2
43	*Anguilla rostrata*	American eel	13,630.0	13,630.0	2
42	*Tubifex tubifex*	Worm	11,145.4	11,145.4	1, 2
41	*Asellus bicrenata*	Isopod	10,658.9	5,731.0	1, 2
	Asellus aquaticus	Isopod		18,200.0	1, 2
	Asellus communis	Isopod		11,610.0	1, 2
40	Midge spp.	Midge	10,545.0	10,544.5	1, 2
39	*Lepomis gibbosus*	Pumpkinseed	10,371.7	18,790.0	2
	Lepomis macrochirus	Bluegill		5,725.0	2
38	*Carassius auratus*	Goldfish	10,250.0	10,250.0	2
37	*Lumbriculus variegatus*	Worm	9,712.0	9,712.0	1, 2
36	*Cyprinus carpio*	Common carp	7,233.0	7,233.0	2
35	*Dugesia tigrina*	Flatworm	7,004.1	7,004.1	1, 2
34	*Echinogammarus tibaldii*	Amphipod	6,792.0	6,792.0	1, 2
33	*Ptychocheilus oregonensis*	Northern squawfish	6,580.0	6,580.0	2
32	*Poecilia reticulata*	Guppy	6,053.0	6,053.0	2
31	*Notemigonus crysoleucus*	Golden shiner	6,000.0	6,000.0	2
30	*Catostomus commersoni*	White sucker	5,228.0	5,228.0	2
29	*Corbicula fluminea*	Asiatic clam	4,900.0	4,900.0	1, 2
28	*Mesocyclops hyalinus*	Copepod	4,846.3	4,846.3	1, 2
27	*Stenocypris malcomsoni*	Ostracod	4,463.7	4,463.7	1, 2
26	*Xiphophorus maculatus*	Southern platyfish	4,341.0	4,341.0	2
25	*Gammarus* sp.	Amphipod	4,323.5	8,100.0	1, 2
	Gammarus italicus	Amphipod		2,307.7	1, 2
24	*Pimephales promelas*	Fathead minnow	3,830.0	3,830.0	2
23	*Lirceus alabamae*	Isopod	3,265.0	3,265.0	1, 2
22	*Salvelinus fontinalis*	Brook trout	1,761.0	1,761.4	1
21	*Lophopodella carteri*	Bryozoan	1,707.0	1,707.0	1, 2
20	*Jordanella floridae*	Flagfish	1,672.0	1,672.0	2
19	*Plumatella emarginata*	Bryozoan	1,607.0	1,607.0	1, 2
18	*Helisoma campanulatum*	Snail	1,578.0	1,578.0	1, 2
17	*Cypris sp.*	Ostracod	1,484.9	1,484.9	1, 2
16	*Physa gyrina*	Snail	1,353.8	1,686.2	1, 2
	Physa heterostropha	Snail		1,087.0	1, 2

TABLE 4: Continued.

Rank	Species	Common Name	GMAV	SMAV	Code
15	*Pectinatella magnifica*	Bryozoan	1,295.9	1,295.9	1, 2
14	*Limnodrilus hoffmeisteri*	Worm	1,258.7	1,258.7	1, 2
13	*Salmo salar*	Atlantic salmon	1,173.4	2,176.0	1
	Salmo trutta	Brown trout		632.7	1
12	*Oncorhynchus mykiss*	Rainbow trout	909.1	617.1	1
	Onchorhynchus kisutch	Coho salmon		1,635.0	1
	Oncorhynchus nerka	Sockeye salmon		1,509.1	1
	Oncorhynchus tshawytscha	Chinook salmon		448.5	1
11	*Ranatra elongata*	Water scorpion	830.6	830.6	1, 2
10	*Tilapia mossambica*	Mozambique tilapia	790.0	790.0	2
9	*Haplodiaptomus viduus*	Copepod	637.7	637.7	1, 2
8	*Catostomus latipinnis*	Flannelmouth Sucker	600.2	600.2	2
7	*Moina irrasa*	Cladoceran	319.4	666.8	1, 2
	Moina macrocopa	Cladoceran		153.0	
6	*Hyalella azteca*	Amphipod	241.3	241.3	1, 2
5	*Agrosia chrysogaster*	Longfin dace	225.8	225.8	2
4	*Daphnia magna*	Cladoceran	214.0	353.5	1, 2
	Daphnia pulex	Cladoceran		253.0	1, 2
	Daphnia spp.	Cladoceran		109.5	1, 2
3	*Cottus bairdi*	Mottled sculpin	159.8	159.8	2
2	*Morone saxatilis*	Striped bass	118.9	118.9	2
1	*Ceriodaphnia dubia*	Cladoceran	94.0	174.1	1, 2
	Ceriodaphnia reticulata	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 (0.8533) 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
New Toxicity vs Hardness Data				
Salmo trutta	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**
Oncorhynchus mykiss	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
	370	5.9135	47	3.8501
	2,510	7.8280	178	5.1818
	430	6.0638	25	3.2189
	7,210	8.8832	330	5.7991
			slope =	**0.910544**
Salvelinus fontinalis	1,550	7.3460	47	3.8501
	2,420	7.7915	44	3.7842
	6,980	8.8508	179	5.1874
			slope =	**0.922304**

Updated Acute Slope Information

Species	n	slope	
Physa heterostropha	12	0.9296	
Daphnia magna	7	1.2549	
Rainbow trout (updated with new data)	33	0.8839	
Brook trout (new data)	9	0.8513	
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	
	124	**0.8533**	**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 (2.4320) 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:

Species	**Ratio**
Oncorhynchus mykiss	1.554
Oncorhynchus tshawytscha	0.7027
Daphnia magna	7.26
*Pimephales promelas**	5.664
*Salvelinus fontinalis**	2.335
*Jordanella floridae***	41.2
EPA acute-chronic ratio =	**1.993973**

New ACR derivation data using data below:

Species	**Ratio**
Daphnia magna	4.5137
Oncorhynchus mykiss	1.5540
Oncorhynchus tshawytscha	0.7027
Salvelinus fontinalis	1.4299
Salmo trutta	1.6809
Cottus bairdi	7.5000
Pimephales promelas	5.6640
Revised Acute-chronic ratio =	**2.4320**

New ACR data from updated toxicity databases:

Species	**Hardness**	**Acute Value**	**Chronic Value**	**Ratio**	**Reference**
Salvelinus fontinalis	60	1,458.0	2,098.0	0.6949	referenced in ERA, USEPA 2002
Salvelinus fontinalis	52.6	932.4	517.5	1.8017	Davies *et al.* 2000
Cottus bairdi	46.3-48.6	156.0	20.8	7.5000	Woodling *et al.* 2002
Salmo trutta	50	392.0	194.0	2.0206	Davies and Brinkman 1999
Salmo trutta	39	550.0	457.0	1.2035	Davies and Brinkman 1994a
Salmo trutta	52.6	540.2	276.6	1.9530	Davies *et al.* 2000
Daphnia spp.	60	128.0	118.0	1.0847	ERA, USEPA 2002

* not used in EPA calculation
** 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 (*Daphnia, Cottus, Morone,* and *Ceriodaphnia*). From these values, a final acute value of 152.8 µg/L was calculated resulting in an updated and revised final acute equation of $e^{0.8533\,[\ln\,(\text{hardness})]\,+\,0.9976}$. Using the new acute-chronic ratio, the resulting updated and revised chronic equation would be $e^{0.8533\,[\ln\,(\text{hardness})]\,+\,0.8021}$. 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.

	Mean Hardness in mg/L $CaCO_3$									
Equations	25	50	75	100	150	200	250	300	350	400
Current Standards										
Acute = $e^{0.8473\,[\ln(\text{hardness})] + 0.8618}$	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 = $e^{0.8533\,[\ln(\text{hardness})] + 0.9976}$	42.28	76.38	107.95	137.99	195.03	249.30	301.59	352.35	401.89	450.39
Chronic = $e^{0.8533\,[\ln(\text{hardness})] + 0.8021}$	34.77	62.82	88.78	113.49	160.40	205.03	248.03	289.78	330.52	370.41

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 23 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
23	Trichoptera	Caddisfly	58,100.0	58,100.0
22	*Nais* sp.	Worm	18,400.0	18,400.0
21	*Chironomus sp.*	Midge	18,200.0	18,200.0
20	*Aeolosoma headleyi*	Worm	17,361.7	17,361.7
19	*Amnicola* sp.	Snail	16,820.0	16,820.0
18	*Tubifex tubifex*	Worm	11,145.4	11,145.4
17	Midge spp.	Midge	10,545.0	10,544.5
16	*Lumbriculus variegatus*	Worm	9,712.0	9,712.0
15	*Dugesia tigrina*	Flatworm	7,004.1	7,004.1
14	*Catostomus commersoni*	White sucker	5,228.0	5,228.0
13	*Corbicula fluminea*	Asiatic clam	4,900.0	4,900.0
12	*Stenocypris malcomsoni*	Ostracod	4,463.7	4,463.7
11	*Salvelinus fontinalis*	Brook trout	1,761.0	1,761.4
10	*Lophopodella carteri*	Bryozoan	1,707.0	1,707.0
9	*Plumatella emarginata*	Bryozoan	1,607.0	1,607.0
8	*Helisoma campanulatum*	Snail	1,578.0	1,578.0
7	*Cypris sp.*	Ostracod	1,484.9	1,484.9
6	*Physa gyrina*	Snail	1,353.8	1,686.2
	Physa heterostropha	Snail		1,087.0
5	*Pectinatella magnifica*	Bryozoan	1,295.9	1,295.9
4	*Limnodrilus hoffmeisteri*	Worm	1,258.7	1,258.7
3	*Ranatra elongata*	Water scorpion	830.6	830.6
2	*Salmo trutta*	Brown trout	632.7	632.7
1	*Oncorhynchus mykiss*	Rainbow trout	617.1	617.1

Subsequently, the site-specific hardness-based equation would be calculated as summarized in Table 9. The resulting acute criteria for dissolved zinc is $e^{0.8533\,[\ln(\text{hardness})] + 2.3130}$. Using this equation and mean site-specific hardness values of 90 mg/L as $CaCO_3$, the site-specific acute dissolved zinc standard is 470.0 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 $e^{0.8533\,[\ln(\text{hardness})] + 2.1174}$. Again, based upon a mean hardness value of 90 mg/L as $CaCO_3$, the site-specific dissolved chronic zinc standard would be 386.5µg/L. When adjusted to two significant digits (U.S. EPA practice) the site-specific standards become 470 µg/L acute and 380 µg/L chronic.

TABLE 9: Recalculation of the final acute and chronic values for zinc with potential non-resident taxa removed (N = 23 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	*Limnodrilus*	1258.7	7.1378	50.9487	0.1667	0.4082
3	*Ranatra*	830.6	6.7221	45.1873	0.1250	0.3536
2	*Salmo*	632.7	6.4500	41.6025	0.0833	0.2887
1	*Oncorhynchus*	617.1	6.4250	41.2810	0.0417	0.2041
		Sum of columns	26.7350	179.0194	0.4167	1.2546

Calculations:
Acute Criterion

$$S^2 = \frac{\text{'}\ (\text{lnGMAV})^2 - (\text{'}\ \text{lnGMAV})^2/4}{\text{'}\ P - (\text{'}\ \%P)^2/4} = \frac{179.0194 - (26.7350)^2 \& 4}{0.4167\ (1.2546)^2 \& 4} = 14.2156 \qquad S = 3.7704$$

L = [' lnGMAV - S(' %P)]/4 = [26.7350 - 3.7704 (1.2546)]&4 = 5.5012
A = S (%0.05) + L = (3.7704)(0.2236) + 5.5012 = 6.3443
Final Acute Value = FAV = e^{A} = 569.2143 CMC = ½ FAV = 284.6071
Pooled Slope = 0.8533

ln (Criterion Maximum Intercept) = lnCMC - [pooled slope × ln (standardized hardness level)]
= ln (284.6071) - [0.8533 × ln (50)]
= 2.3130

Recalculated Acute Zinc Criterion = $e^{0.8533\ [\ln\ (\text{hardness})]\ +\ 2.3130}$ @ Hardness 90 = 470.0 µg/L

Chronic Criterion
Assumed Chronic Slope = 0.8533
Final Acute-to-Chronic ratio (FACR) = 2.4320 (recalculated)

Final Chronic Value (FCV) = FAV ÷ ACR = 569.2143 ÷ 2.4320 = 234.0519

ln (Final Chronic Intercept) = ln FCV - [chronic slope × ln(standardized hardness level)]
= ln (234.0519) - [0.8533 × ln (50)]
= 2.1174

Recalculated Chronic Zinc Criterion = $e^{0.8533\ [\ln\ (\text{hardness})]\ +\ 2.1174}$ @ Hardness 90 = 386.5 µg/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 $e^{0.8533[\ln(hard)]+2.3130}$, and for chronic it is $e^{0.8533[\ln(hard)]+2.1174}$.

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 (µg/L). WQS are based on segment mean hardness of 90 mg/l.

Standard	Hardness (mg/L as $CaCO_3$)	85th Percentile Value	95th Percentile Value	Current Table Value Standards	Recommend Site-Specific Standard
Acute	90	--	110	107	470
Chronic	90	83.2	--	107	380

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 (µmg/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.