Final Report

Boise City Water-Effect Ratio Project

Prepared for

Boise City
Boise, Idaho

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CH2MHILL

Executive Summary

Study Objective and Methodology

Boise City has undertaken a study at the Lander Street and West Boise wastewater treatment plants to determine water-effect ratios (WERs) for copper and lead. The objective of the study is to provide a basis for calculating site-specific criteria (SSC) that can be used to determine appropriate permit limits for lead and copper in effluent discharges to the lower Boise River. This report presents the results of studies to support the development of WERs for lead and copper.

The procedure for developing a WER is based on the assumption that physical and/or chemical characteristics of the mixture of receiving water and effluent at a site may influence the biological availability and toxicity of a metal. Simultaneous toxicity bioassay tests using site water (mixed Boise River and plant effluents) and laboratory water are conducted under identical conditions. The WER is calculated as the ratio of the toxicity in site water to the toxicity in laboratory water.

Study Results

Three rounds of WER tests were conducted for the Lander Street and West Boise wastewater treatment plants with copper and lead. Round 1 and Round 2 tests with *C. dubia* (primary species) were conducted with site water collected under Type 1, low-flow conditions. Round 3 tests with *C. dubia*, fathead minnow (secondary species, copper only), and *H. azteca* (secondary species, lead only) were conducted with site water collected under Type 2, high-flow conditions.

For copper, it was agreed to by all parties that the EPA-published species mean acute value of 11.51 for dissolved copper would be used to determine a final WER. Using the site endpoint values for *C. dubia* under Type 1 and Type 2 flow conditions, this results in a final dissolved WER of 2.578 for copper.

The lead WER values for both species were similar under Type 1 and Type 2 flow conditions. The WER values for all rounds at both sites and for both species were used to calculate the final dissolved WER of 2.049.

Application of the Study Results

The procedure for using the WER to calculate a SSC is as follows:

$$SSC = WQC \times WER_d$$

Where:

SSC = site-specific dissolved water quality criteria
WQC = statewide dissolved water quality criteria (acute or chronic)
WER_d = water-effect ratio (dissolved)

Table ES-1 presents a summary of the current and proposed criteria for copper and lead (at a hardness of 50 mg/L $CaCO_3$) based on the WERs discussed above.

TABLE ES-1
Example Current and Proposed Criteria for Copper and Lead (Hardness of 50 mg/L $CaCO_3$)

	Dissolved Copper	Dissolved Lead
Water-Effect Ratio (WER)	2.578	2.049
Acute		
Current	8.9 µg/L	30 µg/L
Proposed SSC[a]	23 µg/L	62 µg/L
Chronic		
Current	6.3 µg/L	1.2 µg/L
Proposed SSC[a]	16 µg/L	2.4 µg/L

[a] Consistent with 40 CFR 131.36, final criteria are rounded to two significant digits.

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Introduction

To protect aquatic life in the lower Boise River, acute and chronic water quality criteria (WQC) adopted into Idaho state standards are used by the U.S. Environmental Protection Agency (EPA) to calculate effluent permit limits under the National Pollutant Discharge Elimination System (NPDES) program. EPA has included metals limitations for copper and lead in the Boise City's (the City's) 1999 NPDES permits. The purpose of this project was to determine if alternative WQC for copper and lead are appropriate using a water-effect ratio (WER) approach for the Lander Street and West Boise wastewater treatment plants (WWTPs) in Boise, Idaho.

Acute aquatic life criteria protect aquatic organisms from lethal effects resulting from short-term exposure to a given pollutant. Chronic aquatic life criteria protect aquatic organisms from growth and reproduction effects resulting from long-term exposure. National and statewide WQC for freshwater organisms were developed using toxicity bioassay tests in laboratory water. However, because of the unique characteristics present in receiving water, the toxicity of a given chemical may be different in site water (i.e., lower Boise River) compared to its toxicity in laboratory water. The ratio of toxicity in site water to toxicity in laboratory water is the WER and is one approach to developing site-specific criteria (SSC) (EPA 1994a, 1994b). The results of this study will be used to develop appropriate SSC and water-quality-based NPDES permit limits for copper and lead for discharges from the WWTPs to the lower Boise River.

The study plan for this project (CH2MHILL 2001) was developed using the February 1994 *EPA Interim Guidance on Determination and Use of Water-Effect Ratios for Metals* (EPA 1994a). As discussed in the study plan, protocols were also based on discussions and meetings with the Idaho Department of Environmental Quality (DEQ), the agency responsible for setting criteria in Idaho, and EPA Region 10. During the course of the project, EPA issued the *Streamlined Water-Effect Ratio Procedure for Discharges of Copper* (EPA 2001). Because EPA (2001) was not available at the study outset, it could not be followed in entirety. Thus, the data analyses and SSC derivation were done considering both EPA's 1994 and 2001 WER guidance documents. The analyses were completed and the SSC were derived in consultation with DEQ and EPA reviewers.

Background

The City currently operates two WWTPs under NPDES permits issued by EPA. Plant influents include industrial and sanitary wastewater. The Lander Street WWTP and West Boise WWTP are located in Boise, Idaho, (Ada County) and discharge to the lower Boise River as shown in Figure 1. Boise River flows are highly regulated to provide flood control and irrigation using three Boise River reservoirs (Anderson Ranch, Arrowrock, and Lucky Peak). The presence of these features has significantly altered the flow regime in the lower Boise River. Low-flow conditions generally begin in mid-October when irrigation releases from the reservoirs end and extend until flood control releases begin, usually sometime

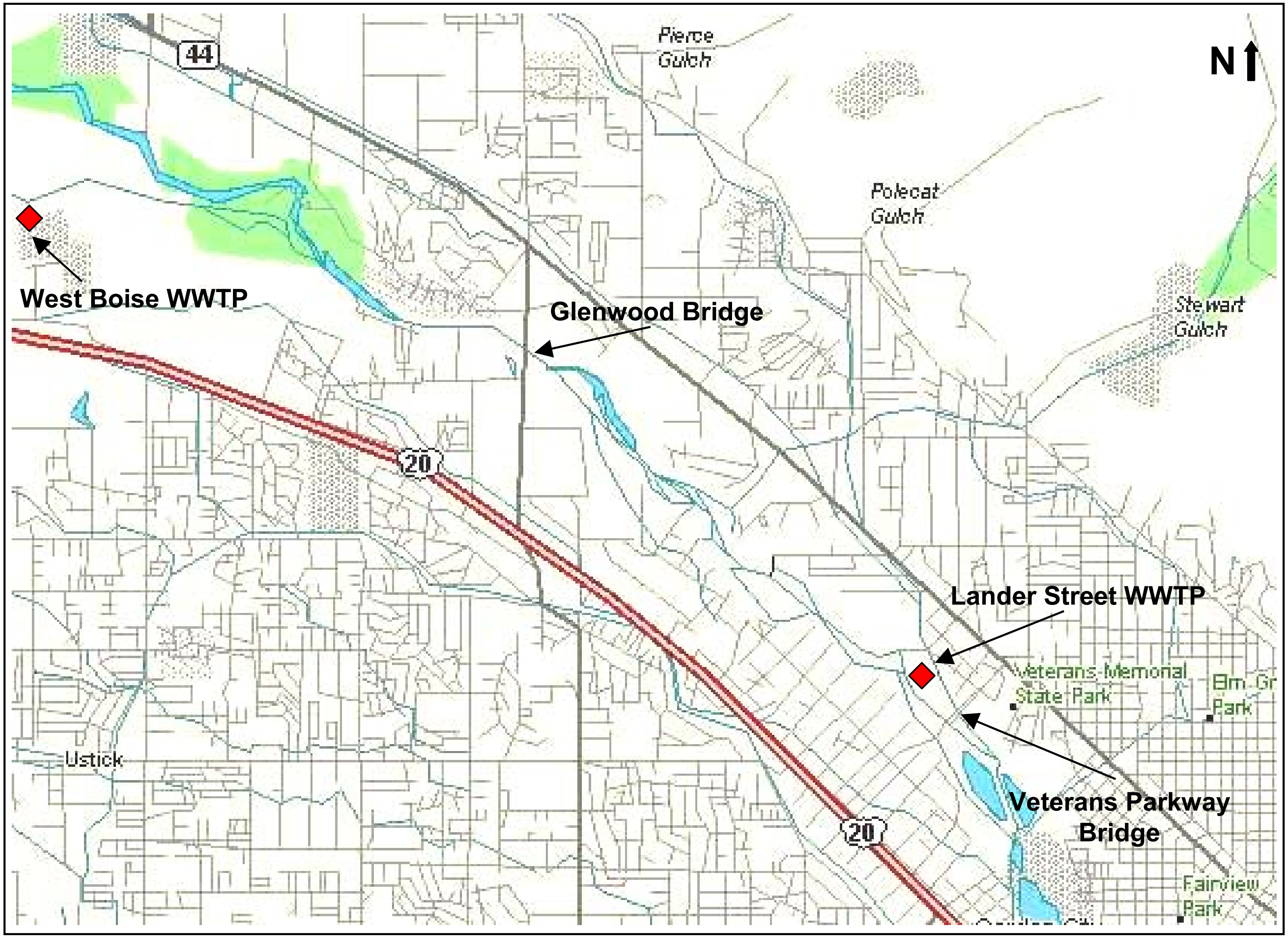

FIGURE 1
Location of Lander Street and West Boise WWTPs

between January and March. Flood flows generally extend through June and irrigation releases occur from July through mid-October. Table 1 presents the design flows of the lower Boise River and the effluent flows.

TABLE 1
Summary of Pertinent Design Flows for the Lander Street and West Boise WWTPs (cfs)

	Lander Street WWTP		West Boise WWTP	
Design Flows	**Apr 1–Sept 31**	**Oct 1–Mar 31**	**Apr 1–Sept 31**	**Oct 1–Mar 31**
Lower Boise River[a]				
1Q10	109	86.0	107	110
7Q10	170	95.0	168	119
WWTP Effluent	23.2	23.2	37.1	37.1

Notes:
[a]The 1-day, 10-year (1Q10) low flows are used for acute toxicity considerations and the 7-day, 10-year (7Q10) low flows are used for chronic toxicity considerations.

Typical river flows are higher than the 1Q10/7Q10 design flow values; winter flows at the Glenwood Bridge (located between the two facilities—Figure 1) average 440 cfs and summer flows average 1,350 cfs. In addition, flow from the West Boise facility is split into a north and south channel.. U.S. Geological Survey (USGS) data recently collected in the south channel indicate a 66 to 34 split between the south and north channel, respectively.

Discharge permits for the Lander Street and West Boise facilities (NPDES Permit No. ID-002044-3 and ID-002398-1, respectively) were reissued by EPA in November 1999 and modified in January 2001. These permits contain limits for copper and lead based on state-adopted baseline WQC for the protection of aquatic life. Table 2 presents a summary of these limits. The permit also included schedule for revised effluent limitations. The copper limits will become effective November 2, 2004, and lead limits will become effective February 12, 2003. Interim permit limits are identified in the footnotes in Table 2.

TABLE 2
Summary of Total Recoverable Permit Limits for Copper and Lead (µg/L)

	Lander Street WWTP				West Boise WWTP			
	Apr 1–Sept 31		Oct 1–Mar 31		Apr 1–Sept 31		Oct 1–Mar 31	
Metal	AML	MDL	AML	MDL	AML	MDL	AML	MDL
Copper	8.7 [a]	14.8	9.9 [a]	16.9	9.9 [b]	20.0	10.4 [b]	21.0
Lead	2.37 [c]	6.00	2.18 [c]	5.51	2.52 [d]	5.50	2.84 [d]	6.18

Notes:
AML—average monthly limit.
MDL—maximum daily limit.
[a]Copper limit effective November 2, 2004; until then the AML = 22.5 µg/L.
[b]Copper limit effective November 2, 2004; until then the AML = 23.3 µg/L.
[c]Lead limit effective February 12, 2003; until then the AML = 8.59 µg/L.
[d]Lead limit effective February 12, 2003; until then the AML = 3.09 µg/L.

Study Objectives

This report documents the results of toxicity tests for copper and lead for the West Boise and Lander Street WWTPs. The City proposes to use the results of this study to develop SSC that will be protective of aquatic communities in the lower Boise River. The WER values presented were determined by conducting several simultaneous toxicity bioassay tests, under identical conditions, using site water (mixed Boise River and WWTP effluents) and laboratory water. The final WER for copper and lead will be applied to the statewide acute and chronic WQC so that site-specific physical and chemical conditions that affect bioavailability and toxicity are reflected accurately.

Reporting Requirements and Report Organization

As specified in the EPA interim guidance document (1994), WER study reports must contain a specific list of items. These items are listed in Table 3 along with the location of where the information can be found in this report. In addition to EPA reporting requirements, the proposed SSC for copper were evaluated to determine if they would likely be protective of rainbow trout (Attachment A).

TABLE 3
Checklist for Required Elements of a WER Study Report

Result Items	Report Location
Investigator and bioassay laboratory information	Appendices C and D
Description of laboratory dilution water	Results, Appendices C and D
Discharger description	Introduction, Methods
Sampling location description	Methods
Sampling procedures	Methods, Appendix A
Laboratory water pre-treatment procedures	Appendix D
Chemical and physical field sample measurements	Results, Appendix B
Experimental bioassay design	Methods, Appendix D
Stock solution preparation	Appendix B
Test organisms description	Appendices C and D
Chemical bioassay measurements	Results, Appendices B and C
Toxicity tests procedures	Appendix D
Differences in side-by-side site and lab waters	Results, Appendix D
Comparison of results between primary and secondary species	Results, Appendices C and D
WER calculations	Results, Discussion, Appendices D and E
Description of final WER calculations	Results, Discussion

Methods

Site Selection

The "site" used for WER and SSC development encompassed two reaches: 1) upstream from the Lander Street WWTP at Veterans Parkway Bridge downstream to the Glenwood Bridge; and 2) upstream from the West Boise WWTP at Glenwood Bridge downstream to the Linder Road Bridge. These reaches were defined as such because effluents are fully mixed upstream of each of the respective downstream bridges. For example, previous dye studies by USGS (1988) have shown the effluent from the Lander Street WWTP to be completely mixed approximately 1.5 miles downstream (Glenwood Bridge) and the effluent from West Boise WWTP to be fully mixed approximately 4 miles downstream (Linder Road Bridge). The upstream locations also correspond to City monitoring stations as specified in the NPDES permits.

In the general context of SSC, a "site" may be a state, region, watershed, waterbody, or segment of a waterbody. For a metals WER, the site should be defined on the basis of expected changes in the material's biological availability and/or toxicity due to physical and chemical variability of site water (EPA 1994a). There are no specific guidelines for defining the physical site boundaries. EPA (1994a) provides the simple advice that a site should neither be too small or too big. If the site is too small, then after investing the resources to develop an acceptable WER, effluent limits could still be excessively constrained by the criteria that apply downstream of the site. If the site is too big, then the costs of developing WERs that characterize the higher physical and chemical variability excepted of a large geographic area could be too high.

In this case, the West Boise WWTP discharges to the southern channel of the Boise River, as Eagle Island splits the river. However, instead of combining the discharge from the West Boise WWTP with the fraction of the river that flowed through the southern channel, it was combined with 100 percent of the river flow as specified in the approved study plan (CH2MHILL 2001). Thus, on the basis of physical and chemical characteristics of the river, the SSC developed from the WER testing could apply downstream of the West Boise WWTP to where the channels around Eagle Island rejoin and 100 percent of the river flows re-occur. At some location downstream of the confluence, the physical and chemical characteristics of the river water would become likely dissimilar from the study area and inappropriate for application of the WER.

The WER is to be adequately protective of the entire site. For example, different WERs could be determined for both the river reaches from the two sampling locations. If all the WERs were sufficiently similar, one SSC could be derived for both reaches. If the WERs were sufficiently different, either the lowest WER could be used to derive one SSC that applies to both reaches, or the data could indicate each reach should be separate "sites," each with its own SSC (EPA 1994a).

Sample Collection

WER sampling included three field events: two events conducted at Type 1 flow conditions and one event conducted at Type 2 flow conditions. Type 1 flow conditions occur when the river flow at the site is equal to or less than twice the design flow conditions (7Q10), and Type 2 flow conditions occur when the river flow is greater than twice but less than 10 times the design flow. However, because the lower Boise River is a regulated river, sampling strictly within these constraints was not possible. As specified in the study plan, flows at the Glenwood Bridge were well below normal because of a relatively dry winter. Therefore, the City targeted the Type 1 events during the winter low-flow period (prior to seasonal irrigation releases) and the Type 2 event during early summer irrigation period. Samples for Type 1 flow conditions were collected in Round 1 on March 26, 2001, and Round 2 on April 12, 2001; both events occurred before the seasonal irrigation flows began. Samples for Type 2 flow conditions were collected during Round 3 on May 21, 2001, following the start of seasonal release of irrigation water.

The City collected the field samples required to support the WER as part of its 2001 Supplemental Water Quality Sampling Program (Boise City 2000). The samples were collected from the lower Boise River upstream of each WWTP discharge. Upstream river water for Lander was collected at Veterans Parkway Bridge and upstream river water for West Boise was collected at Glenwood Bridge (see Figure 1). River samples were collected using equal width-increment, depth-integrated methods. All three field events were conducted at times when the Boise facilities were operating normally. These samples were collected using clean techniques that the City routinely incorporates into its monitoring program, as developed by the City (Boise City 2000).

A 24-hour effluent composite was also taken at each WWTP NPDES monitoring location during Rounds 1, 2, and 3, and was used for the preparation of the simulated downstream site (mixed) water. Plant effluent rates were obtained from plant effluent discharge records over the 24-hour sampling period and converted from millions of gallons per day to cubic feet per second (cfs). The average daily plant discharge was recorded at each plant when the respective samples were collected so that simulated downstream samples could be mixed at the correct ratios. As recommended by the EPA interim guidance document (EPA 1994a), the mixture was prepared to simulate the ratios of effluent and upstream water that existed at the time of sampling so that seasonal and flow-related changes in the water quality characteristics of the upstream water were properly related to the flow at which they occurred. No adjustments for allowable mixing zones were incorporated into the simulated downstream water sample (that is, WER tests were conducted using 100 percent of the river flow to approximate conditions at the fully mixed boundary, below which the statewide criteria apply). In addition, it is important to note that no split factor was used for the West Boise WWTP as specified in the study plan. Using full river flows upstream from the Eagle Island split is conservative because the greater the effluent fraction, the greater the expected WER (that is, municipal effluent represents a source of materials that make metals less bioavailable; EPA 1994a). All mixing activities occurred in the laboratory and the site (mixed) sample was shipped to SF Analytical in Milwaukee, Wisconsin, for bioassay testing on the day of the conclusion of the 24-hour composite effluent sample collection.

Chemical Analyses

The following analyses were conducted on the each of the upstream samples, each of the effluent samples, and each of the site (mixed) samples:

- **Upstream samples:** total recoverable and dissolved copper and lead, total suspended solids (TSS), total organic carbon (TOC), dissolved organic carbon (DOC), hardness, alkalinity, and pH
- **Effluent samples:** total recoverable and dissolved copper and lead, TSS, TOC, DOC, hardness, alkalinity, ammonia, biochemical oxygen demand (BOD), nitrite, and pH
- **Site (mixed) samples:** total recoverable and dissolved copper and lead, TSS, TOC, DOC, hardness (calcium and magnesium), alkalinity, and pH

All chemistry analyses were conducted by the City's laboratory located in Boise, Idaho, which currently performs chemical and biological analysis as required by the current NPDES permits. The lab participates in and complies with EPA's NPDES performance studies and compliance results from this lab have been accepted by EPA. In addition, DEQ inspects the lab on EPA's behalf and collects split samples for the State laboratory yearly. The City laboratory has passed these inspections and sample splits with no comments or requirements from either DEQ or EPA. A laboratory quality assurance project plan (QAPP) is available for review.

The City laboratory analyzed the site (mixed) water for total recoverable copper and lead and for calcium and magnesium while the sample was being shipped to the bioassay laboratory via overnight delivery. SF Analytical used the available metal measurements to account for sample metal concentrations in the bioassays solutions to which the organisms were exposed. As specified in the study plan, SF Analytical used the available cation analysis to prepare the laboratory water so that it had a similar hardness and ratio of calcium to magnesium as that of the site (mixed) water.

Toxicity Tests

Reference Toxicant Testing

Reference toxicant testing with copper and lead was conducted by SF Analytical to establish a quality control check against subsequent WER testing. Toxicity testing was performed with the cladocern *Ceriodaphnia dubia,* fathead minnow (*Pimephales promelas),* and the amphipod *Hyallela azteca*. The 48-hour LC_{50} values (that is, the concentration that is lethal to 50 percent of the organisms) for the toxicity tests were calculated using both total and dissolved metals. A test organism response for a WER test was compared against the responses in the reference toxicant tests as specified in the EPA interim guidance document (1994a).

WER Toxicity Testing

Upon receiving site (mixed) samples, the bioassay lab measured and recorded physicochemical parameters (temperature, pH, alkalinity, hardness, total residual chlorine, and total ammonia) in the sample logbook. Samples that were not used immediately were refrigerated (4 degrees C) for later use, as needed. Toxicity tests were targeted to be initiated no later than 36 hours following sample collection and no tests exceeded the 96-hour holding time stipulated in the study plan.

The EPA interim guidance document (EPA 1994a) states that two species, primary and secondary, should be used for WER testing. As outlined in the study plan, primary tests for copper and lead were conducted using *C. dubia*. Because the secondary species for these tests must also be in different taxonomic orders, fathead minnow (*P. promelas*) was used for secondary tests with copper and *H. azteca* was used for secondary tests with lead. The WER bioassays were conducted according to the standard bioassay protocols specified in the study plan based on EPA methods (EPA 1991, 1994a).

Results

Sample Collection

Table 4 presents river discharges, WWTP flow, and the ratio of mixed effluent and river water used in the Type 1 and Type 2 WERs for both WWTPs. To approximate fully mixed conditions, the effluent was mixed with river water in proportion to 100 percent of the river flows that were measured at the time of sampling (Appendix A). For example, on March 26, 2001, 100 percent river flow was 288 cfs upstream from the Lander Street WWTP, and effluent flow was 18.4 cfs for the Lander Street WWTP, giving a mixing ratio of 0.064 (6.4 percent effluent).

TABLE 4
Lower Boise River Flows, WWTP Discharges, and Mixing Ratios for WER Samples

Sampling Date	Test Round	Flow Type	WWTP Site	Upstream Boise River Flow[a] (cfs)	WWTP Flow[b] (cfs)	Mixing Ratio (WWTP/Boise River)
03/26/2001	1	1	Lander Street	288	18.4	0.064
03/26/2001	1	1	West Boise	319	17.2	0.054
04/12/2001	2	1	Lander Street	342	20.7	0.060
04/12/2001	2	1	West Boise	374	18.5	0.050
05/21/2001	3	2	Lander Street	895	19.3	0.022
05/21/2001	3	2	West Boise	900	19.3	0.021

Notes:
[a] The upstream river flow was the 24-hour average flow that corresponded with the 24-hour composite effluent sampling period. Flows at Glenwood were used to back-calculate the estimated upstream river flows at Lander Street and West Boise (see Appendix A).
[b] The WWTP flow used in the mixing calculations was the daily flow from the period corresponding to the 24-hour composite effluent sampling period.

Rivers flows at the Lander Street facility ranged from 288 to 895 cfs, while plant discharges were relatively constant (18.4 to 20.7 cfs). Thus, the mixing ratio for the Lander Street samples ranged from 6.4 to 2.2 percent. At West Boise river flows ranged from 319 to 900 cfs, and plant discharges again were fairly consistent (17.2 to 19.3 cfs). The mixing ratio for West Boise was similar to Lander Street (5.4 to 2.1 percent).

Chemical Analyses

Table 5 presents the elapsed time between sampling and initiation of toxicity testing is presented. All toxicity tests were started within the allowable holding time of 96 hours and all samples arrived at SF Analytical at temperatures no greater than 4 degrees C.

TABLE 5
Elapsed Time Between Sample Collection and Bioassay Initiation

Test Round	WWTP Site	Test Organism (metal)	Sample Collection		Bioassay Initiation		Time from Collection to Test Initiation (hours)
			Date	Time	Date	Time	
1	Lander	*C. dubia* (copper and lead)	03/26/2001	8:00 a.m.	03/27/2001	3:15 p.m.	31
1	West Boise	*C. dubia* (copper and lead)	03/26/2001	8:00 a.m.	03/27/2001	3:15 p.m.	31
2	Lander	*C. dubia* (copper and lead)	04/12/2001	8:00 a.m.	04/13/2001	3:00 p.m.	31
2	West Boise	*C. dubia* (copper and lead)	04/12/2001	8:00 a.m.	04/13/2001	3:00 p.m.	31
3	Lander	*C. dubia* (copper and lead)	05/21/2001	10:00 a.m.	05/22/2001	2:30 p.m.	29
3	Lander	*P. promelas* (copper) *H. Azteca* (lead)	05/21/2001	10:00 a.m.	05/23/2001	3:00 p.m.	55
3	West Boise	*C. dubia* (copper and lead)	05/21/2001	10:00 a.m.	05/24/2001	3:30 p.m.	78
3	West Boise	*P. promelas* (copper) *H. Azteca* (lead)	05/21/2001	10:00 a.m.	05/25/2001	8:30 a.m.	95

Note:
All times have been converted to central standard time to be consistent.

Table 6 presents the physical/chemical characteristics of the water samples upon arrival at the laboratory. Upon arrival at SF Analytical, dissolved oxygen and pH levels of the samples were also within acceptable levels.

TABLE 6
Chemical/Physical Characteristics of Water Samples Upon Arrival at the Toxicological Laboratory

Test Round	Temperature at Laboratory (^oC)		Dissolved Oxygen (mg/L)		pH (s.u.)	
	Lander Street	West Boise	Lander Street	West Boise	Lander Street	West Boise
1	3	3	9.8	9.9	8.3	8.1
2	3	3	8.6	8.7	8.1	7.9
3	4	4	8.3	8.8	8.1	8.9

Table 7 presents a summary of select constituents that were analyzed for the upstream samples, the effluent samples, and the downstream samples. All raw laboratory data sheets for these field samples, which include additional constituents, are included in Appendix B.

In addition to the observed concentrations, Table 7 also shows the predicted concentrations based on the mixing ratios for each site (mixed) sample for each round. The mixed sample mass balance calculations were determined using the individual discharges (as summarized in Table 4) and concentrations for each of the river and effluent samples (Appendix A). These calculations are provided as a quality assurance check and the results match closely with the actual concentrations in the mixed sample.

TABLE 7
Chemical Constituents of Field Samples

	Total Recoverable Copper, ICP (µg/L)	Dissolved Copper, ICP (µg/L)	Total Recoverable Lead, AA (µg/L)	Dissolved Lead, AA (µg/L)	pH (s.u.)	TSS (mg/L)	TOC (mg/L)	DOC Carbon (mg/L)	Alkalinity (mg/L as $CaCO_3$)	Hardness (mg/L $CaCO_3$)	Calcium (mg/L)	Magnesium (mg/L)
Boise River-Veterans Bridge												
Round 1	3.9	2.1	3.4	<0.6	7.6	32.6	5.2	5.0	45	42	13.3	2.0
Round 2	<1.0	<1.0	1.6	<0.6	7.9	27.8	2.5	2.3	45	38	12.4	1.7
Round 3	<1.0	<1.0	<0.3	<0.6	7.9	1.9	2.0	2.1	44	36	12.2	1.5
Lander Street WWTP												
Round 1	12.6	10.2	0.8	0.8	7.2	14.2	9.3	8.8	95	94	31.4	3.7
Round 2	8.6	7.5	0.5	<0.6	7.6	7.6	8.5	7.0	86	121	41.9	4.0
Round 3	5.7	5.2	0.5	<0.6	7.2	4.4	8.2	7.7	91	137	48.3	3.9
Site (Mixed) Water-Lander Street/Veterans Bridge												
Round 1 (observed)	4.2	2.8	3.5	<0.6	7.6	31.2	5.7	5.3	48	48	15.6	2.2
(predicted based on mixing)	*4.4*	*2.6*	*3.2*	—	*7.6*	*31.5*	*5.4*	*5.2*	*48*	*45*	*14.4*	*2.1*
Round 2 (observed)	1.1	<1.0	1.6	<0.6	7.8	26.7	2.7	2.6	47	43	14.2	1.8
(predicted based on mixing)	—	—	*1.5*	—	*7.9*	*26.6*	*2.8*	*2.6*	*47*	*43*	*14.1*	*1.8*
Round 3 (observed)	<1.0	<1.0	<0.3	<0.6	7.9	2.9	2.0	2.2	44	39	13.0	1.5
(predicted based on mixing)	—	—	—	—	*7.9*	*2.0*	*2.1*	*2.2*	*45*	*38*	*13.0*	*1.6*
Lab Water for Lander Tests												
Round 1	<0.6	<1.0	<0.3	<0.6	—	<1.5	<1.0	1.1	33	55	18.0	2.5
Round 2	<0.6	<1.1	<0.3	<0.6	—	<1.5	<1.0	1.3	27	45	14.9	1.9
Round 3	<0.6	<1.1	0.4	<0.6	—	<1.5	<1.0	3.6	28	47	15.4	2.1
Boise River-Glenwood Bridge												
Round 1	5.5	2.5	2.2	<0.6	7.8	34.4	5.7	5.2	50	49	16.0	2.2
Round 2	1.2	<1.0	1.5	<0.6	7.8	22.4	2.8	2.7	47	43	14.1	1.8
Round 3	<1.0	1	<0.3	<0.6	8.7	4.0	2.2	2.3	46	40	13.3	1.5
West Boise WWTP												
Round 1	20.7	16.7	0.5	<0.6	7.5	11.4	11.5	10.4	80	110	32.7	6.9
Round 2	18.9	16.2	<0.3	<0.6	7.3	11.2	11.3	10	48	128	40.2	6.8
Round 3	13.8	8.7	<0.3	<0.6	7.8	5.6	6.7	6.5	106	131	40.4	7.3
Site (Mixed) Water-West Boise/Glenwood Bridge												
Round 1 (observed)	5.3	3.3	2.2	<0.6	7.8	32	6.0	5.3	53	53	17.0	2.5
(predicted based on mixing)	*6.3*	*3.2*	*2.1*	—	*7.8*	*33.2*	*6.0*	*5.5*	*52*	*52*	*16.9*	*2.4*
Round 2 (observed)	2.2	<1.0	1.4	<0.6	7.8	21.6	3.2	3.0	47	47	15.4	2.1
(predicted based on mixing)	*2.1*	—	—	—	*7.8*	*21.9*	*3.2*	*3.1*	*47*	*47*	*15.4*	*2.0*
Round 3 (observed)	<1.0	<1.0	<0.3	<0.6	8.6	4.0	2.3	2.4	47	41	13.7	1.6
(predicted based on mixing)	—	*1.4*	—	—	*8.7*	*4.1*	*2.4*	*2.5*	*49*	*44*	*14.6*	*1.8*
Lab Water for West Boise Tests												
Round 1	<0.6	<1.0	<0.3	<0.6	—	<1.5	<1.0	1.2	32	58	18.6	2.8
Round 2	<0.6	<1.1	<0.3	<0.6	—	<1.5	<1.0	1.3	28	46	15.4	1.9
Round 3	<0.6	<1.1	<0.3	<0.6	—	<1.5	1.0	<1.0	28	48	15.6	2.1

Notes: AA = atomic adsorption; ICP = inductively coupled plasma; NA = Not analyzed; — = Not able to be calculated because of non-detected values

Toxicity Tests

Reference Toxicant Testing

The LC_{50} values obtained in laboratory water during the WER tests were corroborated by comparing the WER laboratory water results with a minimum of three reference toxicant tests using metal concentrations (copper sulfate and lead nitrate) at the expected site water hardness (50 mg/L ± 5 mg/L).

A summary of the results of the reference toxicant tests is presented in Table 8 and complete bioassay reports are included in Appendix C.

TABLE 8
Summary of LC_{50} Values for Reference Toxicant Testing (µg/L)

C. dubia				Fathead Minnow		*H. azteca*	
Copper		Lead		Copper		Lead	
Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
2.9	2.6	140.6	126.5	131.6	122.6	56.2	51.9
1.9	1.5	214.7	188.0	64.1	57.6	32.9	31.1
2.3	1.7	157.3	139.8	60.5	61.2	61.7	54.0

All LC_{50} values for the WER laboratory tests (see Tables 9 and 10) were within a factor of 3 of the average reference toxicant LC_{50} values.

WER Toxicity Testing

A summary of LC_{50} values for dissolved copper and lead WER toxicity tests with *C. dubia*, fathead minnow, and *H. azteca* is presented in Table 9. LC_{50} concentrations and WER values for total recoverable copper and lead are presented in Table 10. Combined WER values using data from both sites for dissolved and total recoverable metals are provided in the last columns in Tables 9 and 10, respectively. The combined WER values were calculated using an adjusted geometric mean methodology (EPA 1994a).

TABLE 9
Summary of LC_{50} Concentrations and WER Results for Dissolved Copper and Lead

	Lander Street			West Boise			
	Lab LC_{50} (µg/L)	Site LC_{50} (µg/L)	WER	Lab LC_{50} (µg/L)	Site LC_{50} (µg/L)	WER	Combined WER
Copper							
Round 1							
C. dubia	1.881	39.30	20.89	3.627	60.15	16.58	17.55
Round 2							
C. dubia	1.100	23.10	21.00	1.739	30.30	17.42	18.24
Round 3							
C. dubia	1.504	18.63	12.39	2.653	22.13	8.342	9.191
Fathead	82.26	147.2	1.789	56.25	214.3	3.810	2.154
Adj. WERs (C. Dubia Rounds 1 and 2)			*20.92*			*16.79*	*18.39*
Lead							
Round 1							
C. dubia	322.2	>424.0	>1.316	219.6	329.4	1.500	>1.359
Round 2							
C. dubia	122.3	233.8	1.911	181.5	966.5	5.325	2.457
Round 3							
C. dubia	194.1	210.6	1.085	226.7	369.7	1.631	1.199
H. azteca	32.70	105.9	3.239	24.00	132.8	5.533	3.693
Adj. WERs (Both Species, All Rounds)			*1.557*			*2.501*	*2.049*

Notes:
As specified in the EPA interim guidance document (EPA 1994a) all LC_{50} and WER values are presented to four significant digits.

Results from all rounds are dissolved values based on final analytical results (Appendix B). All combined values were calculated using adjusted geometric means (EPA 1994a). The adjusted geometric mean procedure is demonstrated in the following equation:

WER = antilog [mean-$t_{0.7}$ x SE]
where:

WER = water effect ratio
mean = geometric mean of logarithms of individual WERs
$t_{0.7}$ = value of Student's t statistic for one-sided probability of 0.7 with n-1 degrees of freedom
SE = standard error of the arithmetic mean

TABLE 10
Summary of LC_{50} Concentrations and WER Results for Total Recoverable Copper and Lead

	Lander Street			West Boise			
	Lab LC_{50} (µg/L)	**Site LC_{50} (µg/L)**	**WER**	**Lab LC_{50} (µg/L)**	**Site LC_{50} (µg/L)**	**WER**	Combined **WER**
Copper							
Round 1							
C. dubia	3.062	60.85	19.88	3.764	86.25	22.92	20.41
Round 2							
C. dubia	2.400	39.45	16.44	2.111	38.20	18.10	16.87
Round 3							
C. dubia	2.064	22.79	11.04	3.473	28.76	8.281	8.887
Fathead	87.60	159.5	1.821	68.14	288.4	4.232	2.239
Adj. WERs (C. Dubia Rounds 1 and 2)			*17.19*			*19.26*	*18.60*
Lead							
Round 1							
C. dubia	330.0	>928.0	>2.812	245.2	745.8	3.042	>2.867
Round 2							
C. dubia	128.9	643.3	4.991	200.2	2960	14.79	6.514
Round 3							
C. dubia	193.3	269.1	1.392	232.1	498.8	2.149	1.549
H. azteca	35.96	153.7	4.274	48.90	157.6	3.223	3.454
Adj. WERs (Both Species, All Rounds)			*2.678*			*3.502*	*3.228*

Note:
Results from all rounds are total recoverable values based on final analytical results (Appendix B). All combined values were calculated using adjusted geometric means (EPA 1994a). The adjusted geometric mean procedure is demonstrated in the following equation:

WER = antilog [mean-$t_{0.7}$ x SE]
where:

WER = water effect ratio
mean = geometric mean of logarithms of individual WERs
$t_{0.7}$ = value of Student's t statistic for one-sided probability of 0.7 with n-1 degrees of freedom
SE = standard error of the arithmetic mean

Chemical analyses for site (mixed) samples and laboratory dilution water used in the WER tests are in Appendix B, laboratory reports for the WER toxicity tests are provided in Appendix D, and a complete summary of the LC_{50} concentrations and WER calculations are included in Appendix E. LC_{50} values in side-by-side tests were calculated using identical methods (for example, probit or linear interpolation) according to EPA interim guidance document (EPA 1994a) recommendations. The laboratory reports in Appendix D provide the ToxCalc statistical software output, which includes 95 percent confident limits for each LC_{50} value that was calculated.

With the exception of one test in Round 1, survival was lower than 50 percent for the highest concentration of metals used in all the tests, which means than an LC_{50} could be calculated for the majority of tests. For the Round 1 tests at Lander Street using *C. dubia* to test lead in site water, only 30 percent of the organisms died at the highest concentration of lead. Therefore, the actual LC_{50} value for dissolved lead was >424 µg/L and for total lead the LC_{50} value was >928 µg/L. To be conservative, a dissolved lead LC_{50} of 424 µg/L for the site water was used to calculate the dissolved lead WER and a total lead LC_{50} of 928 µg/L for the site water was used to calculate the total lead WER.

Quality Assurance/Quality Control Samples

As specified in the study plan, quality assurance/quality control (QA/QC) samples were collected throughout the testing program. All of these blanks had concentrations of total and/or dissolved copper and lead that were either at or below normal method detection limits (MDLs) of 0.6 to 1.1 µg/L for copper and 0.3 to 0.6 µg/L for lead. In comparison to the spiked concentrations of copper (ranging as high as 420 µg/L) and lead (ranging as high as 3,800 µg/L), these concentrations are minute and the MDLs were acceptable.

The following QA/QC samples were collected:

- **Stock Solution**—To confirm that the stock solution of copper and lead contained the expected concentrations of each metal, these solutions were submitted for analysis. These samples confirmed that the stock solution was within 5 percent of the expected concentration.
- **Bottle Blanks**—One bottle blank was submitted for analysis, which confirmed no detected concentrations of copper or lead in the blank.
- **Reference Toxicant Tests**—Four laboratory water and filter blanks were submitted for analysis, which confirmed no detected concentrations of copper or lead in any of the blanks.
- **Round 1 WER Tests**—Two laboratory water blanks (one for each site), one unfiltered blank, and two filter blanks (one for each site) were submitted for analysis, which confirmed no detected concentrations of copper or lead in any of the blanks.
- **Round 2 WER Tests**—Two laboratory water blanks (one for each site) and two filter blanks (one for each site) were submitted for analysis, which confirmed no detected concentrations of copper or lead in any of the blanks.
- **Round 3 WER Tests**—Two laboratory water blanks (one for each site) and four filter blanks (one for each site for each organism) were submitted for analysis, which confirmed no detected concentrations of copper or lead in any of the blanks.

The results of the laboratory water blanks for each site are summarized in Table 7.

In addition to these samples, analytical laboratory QA/QC samples included sample replicates, matrix spikes, certified reference materials, initial calibration verifications and continuous calibration verifications, method blanks, and fortified reagent blanks. All of these samples were within acceptable limits.

Discussion

Combining Lander Street and West Boise Site Data

There does not appear to be substantial differences in site toxicity endpoints between the two sites. As discussed in the study plan, if the WERs for both plants turned out to be essentially the same, a single WER may be able to be applied to a combined "site." Although the "site" used for WER and SSC development originally extended from upstream from the Lander Street WWTP at Veterans Parkway Bridge downstream to the Linder Road Bridge, for the purposes of incorporating the WER into the Idaho rulemaking process, the site to which the WER is applicable may be able to be extended below the confluence of Eagle Island because the discharge from the West Boise WWTP was combined with 100 percent of the river flow as measured above the confluence at the time of each sampling event. Downstream from the site, statewide criteria would still apply.

Similar dissolved values were obtained for specific organisms at each site (Table 9). For example, *C. dubia* dissolved copper site endpoint values from low-flow Rounds 1 and 2 are relatively consistent between sites (ranging between 23.10 and 60.15 µg/L). Because the endpoint data from the two sites appear to follow the same general trends, results for the individual plants should be combined in the determination of the final WER.

The dissolved WER will be applied to Idaho's statewide dissolved criteria and the total recoverable WER is used as a QC check. For comparison, the total recoverable endpoints for copper and lead also were similar for specific organisms at each site (Table 10). These results support the findings of the dissolved WERs and the conclusion that the two sites should be combined to calculate a final WER for both metals.

Copper Results

WER Guidance Recommendations and River Flow Considerations

Throughout this discussion all copper concentrations, including the derivation of acute and chronic SSC, are normalized to 50 mg/L $CaCO_3$ hardness.

State regulations (IDAPA 58.01.02.210.03; IDAPA 58.01.02.275) specifically reference the determination of SSC using EPA's WER guidance documents . According to recommendations in the 1994 WER interim guidance document (EPA 1994a), the final WER is calculated as the adjusted geometric mean of the individual WERs for the most sensitive, primary species (*C. dubia*) tested under Type 1 flow conditions. Relying on Type 1 flow conditions follows a similar rationale for determining typical NPDES permit limits (that is, normal or design effluent flows discharging into low-flow receiving waters). In this case, flows during Rounds 1 and 2 were considered low-flow Type 1 events because receiving water flows were less than twice the 7Q10 in the lower Boise River. Ultimately, it was agreed to by all parties to use results from all three rounds to determine the final WER.

Because including the results from the high-flow Type 2 event (Round 3) caused the final WER to go down, this decision is considered protective.

Although the Boise WER workplan was developed using the EPA 1994 interim guidance document (EPA 1994a), the EPA 2001 streamlined copper procedures are somewhat different. EPA (1994a) considers the ratio of toxicity in site water to toxicity in laboratory water to be the WER. However, based upon experience using the interim guidance, EPA (2001) considers the ratio of toxicity to a test species in site water to the *higher* of either the toxicity in laboratory water *or* the toxicity in the national criterion dataset. The concept of a WER is to modify a national criterion based on differences between the toxicity of copper in site water and in the laboratory waters used to derive the national criterion. Fundamentally, the comparison between site water values and national datasets are the most relevant since it is the national dataset that is being modified by the WER. As the streamlined document states, this procedure "eliminates... the variability and apparent non-protective bias of the lab water ordinarily used in the side-by-side tests."

Since both *C. dubia* and fathead minnow LC_{50} values appeared lower than the species mean acute values (SMAVs) given in EPA (1984a) and EPA (2001), additional analyses were performed to compare laboratory values from this study with those from the national datasets (Attachment B). Because the analyses showed that the *C. dubia* laboratory dataset for copper in this study was lower than the national dataset presented in EPA (2001), it was agreed to by all parties that an fWER value should be derived using calculation procedures recommended in the streamlined WER document (EPA 2001).

Specifically, the streamlined document advises that a sample WER is the "lesser of the (i) the site-water EC_{50} divided by the lab water EC_{50}, or (ii) the site-water EC_{50} divided by the SMAV." This means that either the higher of the laboratory dataset value(s) or the SMAV should be used as denominator in the WER ratio. This causes the final WER value to go down, so this procedure can be considered protective because it results in relatively lower SSC.

The streamlined document provides three pathways for deriving SSC from a WER. For comparison, any of these variations are supported by the data, can be logically argued, and provide nearly identical results. Primarily because Idaho's current statewide standards are expressed as dissolved values, all parties agreed that the dissolved streamlined approach should be used to determine the final WER. Taking this approach, which leads to dissolved SSC, also mitigates issues with the downstream boundaries because it eliminates the need for an additional translator exercise to evaluate downstream compliance during the permit-writing phase.

A summary of calculations is provided in Tables 11 and 12.

TABLE 11
Summary of Available Site Toxicity *C. dubia* Endpoints for Copper (µg/L, dissolved)

Series	Lander	West Boise
Round 1	39.30	60.15
Round 2	23.10	30.30
Round 3	18.63	22.13

TABLE 12
Summary of Dissolved Streamlined WERs for Copper (*C. dubia* Site Endpoints divided by the SMAV; µg/L, dissolved)

Series	Lander	West Boise
Round 1	39.30 / 11.51 = 3.414	60.15 / 11.51 = 5.226
Round 2	23.10 / 11.51 = 2.007	30.30 / 11.51 = 2.632
Round 3	18.63 / 11.51 = 1.619	22.13 / 11.51 = 1.923
Geomean Final WER for Both Sites	*2.578*	

As published in the streamlined document (EPA 2001), the dissolved SMAV for *C. dubia* is 11.51 µg/L.

These calculations show that the fWER that should be applied to the statewide acute and chronic dissolved criteria should be 2.578.

It is important to note that all parties have agreed that the use of a SMAV from the streamlined document is the only part of the streamlined approach that is being applied to this project. The procedures for conducting a WER study under the streamlined approach were developed to apply to specific situations (i.e., where most of the cooper is from continuous point source effluents, where the copper from the regulated discharge is expected to attain its maximum concentrations under low-flow or low-dilution conditions). However, the Boise City situation specifically precluded the use of the streamlined sampling approach due to 1) multiple metals, and 2) suspected minimum concentrations under low-flow or low-dilution conditions when municipal effluent represented a source of materials that make metals non-bioavailable. The dilution issue was specifically addressed during study plan development because it was agreed to that the site samples would be tested at 100 percent of the river flow, rather than 25 or 50 percent, to ensure the outcome was conservative and protective of the river downstream.

Thus, the samples for this study were combined at the ratio that existed at the time of sampling according to procedures specified in the EPA interim guidance document (EPA 1994a), not at the design ratio as specified in the streamlined document (EPA 2001). To confirm the assumption that the sampling approach used provides a higher level of protection than the streamlined methodology (for this specific site), site endpoints from the lower flow events were compared with site endpoints from higher flow events. During low-flow Rounds 1 and 2 (geometric mean mixing ratio of 5.7 percent), the site geometric mean dissolved LC_{50} was 35.9 µg/L. In contrast, during high-flow Round 3 (geometric mean mixing ratio of 2.1 percent), the site geometric mean dissolved LC_{50} was 20.3 µg/L. This confirms the original assumption that when the effluent concentration is higher under low-flow conditions, the copper appears to be less bioavailable and the site endpoints are higher.[1]

[1] Once criteria are derived, the City's permit limits will be calculated under low-flow and design conditions as summarized in Table 1. This means that less receiving water is available for dilution, which results in more stringent permit limitations. For this site, using criteria developed under variable-flow conditions to calculate permit limits for low-flow conditions provides a conservative combination, as highlighted further in the HCME/hWER analysis. This conservative combination may not be appropriate for other studies with other site-specific considerations.

Thus, although the streamlined procedure calls for site samples to be mixed at design conditions, the fact that our site samples were mixed at a more protective ratio (i.e., when effluent concentrations were lower and copper was more bioavailable) should not preclude the use of the SMAV in the streamlined guidance. In fact, using the SMAV in lieu of our laboratory dataset just adds another conservative step to the fWER value because it results in a relatively lower fWER value and subsequent SSC.

The proposed fWER of 2.578 was also compared to other available studies. Brungs et al. (1992) reported that eight copper WER studies (using five different species) had total recoverable WERs ranging between 1.0 and 15.3 (mean 5.4). At the Clark Fork River site, acute and chronic copper WERs ranged from 1.56 to greater than 25.6 for total recoverable copper (mean 2.7) and from 1.04 to 10.6 for dissolved copper (mean 2.2; EPA 1999). Thus, it appears that the proposed fWER of 2.578 for copper is consistent with other WER studies that have been conducted.

Calculation of Potential SSC

The dissolved acute SSC at 50 mg/L $CaCO_3$ hardness is calculated by multiplying the existing acute dissolved copper criterion (criteria maximum concentration [CMC]) of 8.856 µg/L by the revised dissolved WER of 2.578 for a potential acute dissolved SSC of 22.83 µg/L for copper[2].

The chronic criteria (criteria continuous concentration [CCC]) is calculated in the copper criteria document (EPA 1984a) based on an acute to chronic ratio (ACR) methodology. At 50 mg/L $CaCO_3$ hardness, the existing dissolved CCC is 6.277 µg/L. A chronic dissolved SSC for copper of 16.18 µg/L at 50 mg/L $CaCO_3$ hardness is determined by multiplying the existing CCC of 6.277 µg/L times the dissolved WER of 2.578[2].

Evaluation of Potential SSC for Locally Important and Sensitive Species

At DEQ's request, the proposed SSC for copper were also evaluated to ensure that they are protective of locally important and sensitive species (Attachment A). Rainbow trout are being used in this analysis because they represent a relatively sensitive vertebrate in comparison to other salmonids, including brown trout or mountain whitefish (EPA 1999, Welch et al. 1998), which are other game fish present at the site. Although the rainbow trout found in the lower Boise River are primarily stocked adult fish, early life stage (ELS) data are used in the analysis because the ELS is more sensitive to toxicity caused by copper than adult fish and protection of ELS organisms provides a reasonable surrogate for protecting naturally reproducing populations of other salmonids. Available data from other studies (Attachment A) suggest that the site-specific dissolved copper concentration that would be expected to cause zero mortality to ELS rainbow trout is estimated at 29.5 µg/L. Thus, the proposed acute CMC of 23 µg/L appears to be protective of locally important species.

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[2] Again, the statewide dissolved criteria are expressed as a function of hardness. Thus, for practical application, the SSC that will apply to this site will be expressed as the WER of 2.578 for copper times the statewide acute and chronic criterion equations.

Lead Results

WER Guidance Recommendations and River Flow Considerations

According to the guidance, the WER for lead should be calculated as the adjusted geometric mean of the individual WERs for the most sensitive, primary species (*C. dubia*) tested under Type 1 flow conditions.

Unlike copper, in this case there does not appear to be a clear difference in bioavailability between low-flow and high-flow events. For example, the combined WER for *C. dubia* during Round 3 flows (1.199) is only slightly lower than the combined WER for Round 1 (1.359) and Round 2 (2.457). Therefore, all rounds of data for Type 1 and Type 2 flow conditions can be used to determine the WER for lead.

The study plan followed the guidance-recommended toxicity tests for lead (that is, using *C. dubia* and *H. azteca*). *H. azteca* was used in this case as a substitute for the original secondary species for lead (*Gammarus pseudolimnaeus*) because of difficulties in obtaining ELS organisms. Data used to develop the study plan showed that *C. dubia* was more sensitive than *G. Pseudolimnaeus*, and because *H. azteca* is closely related to *G. pseudolimnaeu*s it was expected that their sensitivities would be similar. However, the results of the study show that *H. azteca* is more sensitive in laboratory water than *C. dubia* (Tables 9 and 10) and the more sensitive species produced the higher WER under Type 2 flows.

Because there does not appear to be a substantial difference in WERs for *C. dubia* for the Type 1 and Type 2 flows, it was decided to calculate the final WER for lead using data for both species for all rounds. Based on the dissolved WER values for both *C. dubia* (all three rounds) and *H. azteca* (Round 3), the adjusted geometric mean dissolved WER would be 2.049.

Calculation of Potential SSC

To derive the dissolved acute SSC, the existing acute dissolved criterion (CMC) of 30.14 µg/L (EPA 1984b) is multiplied by the proposed dissolved WER of 2.049. This gives an acute dissolved SSC of 61.76 µg/L for lead at 50 mg/L $CaCO_3$ hardness[3].

The existing chronic criteria (CCC) is calculated as 1.174 µg/L at 50 mg/L $CaCO_3$ hardness (EPA 1984b). A similar calculation is performed to determine the chronic dissolved SSC for lead of 2.406 µg/L at 50 mg/L $CaCO_3$ hardness (existing CCC of 1.174 µg/L times the dissolved WER of 2.049)[3].

Evaluation of Potential SSC for Locally Important and Sensitive Species

To evaluate the protectiveness of the proposed SSC, the dissolved acute SSC (CMC) of 62 µg/L and chronic SSC (CCC) of 2.4 µg/L were compared against data obtained in this and other studies. During acute testing in this study, the geometric mean dissolved lead concentration in site water at which 50 percent of the *C. dubia* survived was 382 µg/L. The

[3] Again, the statewide dissolved criteria are expressed as a function of hardness. Thus, for practical application, the SSC that will apply to this site will be expressed as the WER of 2.049 for lead times the statewide acute and chronic criterion equations.

geometric mean site LC_{50} for *H. azteca* was 103 µg/L. Thus, the proposed CMC and CCC are both much lower than the site LC_{50} endpoints for both of the sensitive species tested.

In terms of protecting locally important species, in the current criteria document the SMAV for rainbow trout is 2,448 µg/L (EPA 1984b). This value is consistent with the revised SMAV presented in the draft lead criteria update (EPA 1998) of 2,057 µg/L. Thus, the proposed acute and chronic SSC for lead appear to be protective of rainbow trout.

HCME/HWER Evaluation

The EPA interim guidance document (1994a) requires that WERs observed in the bioassay tests be compared against predicted WERs at design flows (Table 1). As specified in the study plan, for each individual WER, the highest concentration of metal in the effluent (HCME) is calculated from the following formula:

$$HCME = \frac{[CCC * WER * (Q_e + Q_u)] - [(C_u * Q_u)]}{Q_e}$$

Where:

CCC	=	Metal statewide toxicity criterion
Q_e	=	Effluent flow at time of sample collection
Q_u	=	Upstream flow at time of sample collection
C_u	=	Upstream metal concentration at time of sample collection

In situations where a steady-state model was used to derive permit limits, the effluent limits typically apply at all flows. Therefore, each HCME is used to calculate the highest WER (hWER) that could be used to derive a SSC for the downstream water at design flow. This calculation is done to provide adequate water quality protection at the flow when the sampling was conducted. The hWER is calculated as:

$$hWER = \frac{(HCME * Q_{ed}) + (C_{ud} * Q_{ud})}{CCC * (Q_{ed} + Q_{ud})}$$

Where:

Q_{ed}	=	Effluent design flow
C_{ud}	=	Upstream metal concentration at design flow (background)
Q_{ud}	=	Upstream design flow

These calculations for each WER for each round at both sites are presented in Table 13. For these calculations, it was assumed that the C_{ud} was zero because this assumption is environmentally conservative (that is, it produces a lower hWER). Also, the 7Q10 design flow was used as the Q_{ud} because it also causes the hWER to be lower as compared to using the 1Q10 design flow. Using the 7Q10 is also appropriate because this design flow is used for chronic toxicity considerations and the chronic criteria drive the most stringent permit limits.

Table 13 shows that the hWER values for all rounds for both metals at both sites are substantially higher than the WERs derived from the bioassay tests. This indicates that the observed WERs should be used to determine the final WER values for both metals. (As a confirmation, the final WER values discussed in the following section produce an identical conclusion; that is, the calculated hWER values are higher than the final WER values. Because the lowest hWERs for copper and lead are 1.7 and 1.6 times higher, respectively, than the final WER values, the final WER values are used to determine the SSC for both metals.)

TABLE 13
HCME and HWER Calculations

	COPPER										LEAD									
	Lander Street WWTP					West Boise WWTP					Lander Street WWTP					West Boise WWTP				
	Inputs[a]		HCME	hWER		Inputs[a]		HCME	hWER		Inputs[a]		HCME	hWER		Inputs[a]		HCME	hWER	
	S	W		S	W	S	W		S	W	S	W		S	W	S	W		S	W
CCC (ug/L)[b]	6.28	- -	- -	- -	- -	6.28	- -	- -	- -	- -	1.17	- -	- -	- -	- -	1.17	- -	- -	- -	- -
Q_{ed} (cfs)	23.2	- -	- -	- -	- -	37.1	- -	- -	- -	- -	23.2	- -	- -	- -	- -	37.1	- -	- -	- -	- -
C_{ud} (ug/L)[c]	0	- -	- -	- -	- -	0	- -	- -	- -	- -	0	- -	- -	- -	- -	0	- -	- -	- -	- -
Q_{ud} (cfs)[d]	170	95	- -	- -	- -	168	119	- -	- -	- -	170	95	- -	- -	- -	168	119	- -	- -	- -
Round 1																				
Q_e (cfs)	18.4	- -	- -	- -	- -	17.2	- -	- -	- -	- -	18.4	- -	- -	- -	- -	17.2	- -	- -	- -	- -
Q_u (cfs)	288	- -	- -	- -	- -	319	- -	- -	- -	- -	288	- -	- -	- -	- -	319	- -	- -	- -	- -
C_u (ug/L)	2.1	- -	- -	- -	- -	2.5	- -	- -	- -	- -	0.6	- -	- -	- -	- -	0.6	- -	- -	- -	- -
WER (obs)	20.89	- -	2152	41.1	67.3	16.58	- -	1989	57.3	75.3	1.316	- -	16	1.7	2.7	1.500	- -	23	3.6	4.7
WER (neg)[e]	2.578	- -	237	4.5	7.4	2.578	- -	270	7.8	10.2	2.049	- -	31	3.1	5.1	2.049	- -	36	5.5	7.3
Round 2																				
Q_e (cfs)	20.7	- -	- -	- -	- -	18.5	- -	- -	- -	- -	20.7	- -	- -	- -	- -	18.5	- -	- -	- -	- -
Q_u (cfs)	342	- -	- -	- -	- -	374	- -	- -	- -	- -	342	- -	- -	- -	- -	374	- -	- -	- -	- -
C_u (ug/L)	1.0	- -	- -	- -	- -	1.0	- -	- -	- -	- -	0.6	- -	- -	- -	- -	0.6	- -	- -	- -	- -
WER (obs)	21.00	- -	2,294	43.9	71.7	17.42	- -	2,301	66.3	87.1	1.911	- -	29	3.0	4.9	5.325	- -	120	18.6	24.4
WER (neg)[e]	2.578	- -	267	5.1	8.3	2.578	- -	323	9.3	12.2	2.049	- -	32	3.3	5.4	2.049	- -	39	6.0	7.9
Round 3																				
Q_e (cfs)	19.3	- -	- -	- -	- -	19.3	- -	- -	- -	- -	19.3	- -	- -	- -	- -	19.3	- -	- -	- -	- -
Q_u (cfs)	895	- -	- -	- -	- -	900	- -	- -	- -	- -	895	- -	- -	- -	- -	900	- -	- -	- -	- -
C_u (ug/L)	1.0	- -	- -	- -	- -	1.0	- -	- -	- -	- -	0.6	- -	- -	- -	- -	0.6	- -	- -	- -	- -
WER (obs)	12.39	- -	3,640	69.6	113.8	8.342	- -	2,449	70.5	92.7	1.085	- -	32	3.3	5.4	1.631	- -	63	9.7	12.8
WER (neg)[e]	2.578	- -	721	13.8	22.5	2.578	- -	725	20.9	27.4	2.049	- -	86	8.8	14.4	2.049	- -	86	13.3	17.5

S- Summer, W- Winter
See text for definitions of other acronyms.
Notes:
[a] Inputs for summer and winter are identical with the exception of the Q_{ud} (7Q10), which is dependent on season.
[b] The criterion used in these calculations is the chronic criterion at a hardness of 50 mg/L $CaCo_3$.
[c] It is an environmentally conservative assumption to treat C_{ud} (background) as zero because it causes the hWER to be lower (EPA 1994a).
[d] It is an environmentally conservative assumption to use the chronic 7Q10 as the Q_{ud} because it causes the hWER to be lower.
[e] Although the HCME and hWER calculations are supposed to be calculated using the observed WER (i.e., the WER determined by bioassay testing), this analysis uses the negotiated WER to be conservative and to meet the intent of the guidance. Final hWER values are outlined for comparison against the negotiated WERs (which are all smaller than the calculated lowest hWER values).

Data Acceptability

Bioassay Results

As indicated earlier, the bioassay results for the Boise WER study were generally acceptable for deriving WERs (with the exception of the toxicity tests conducted on copper with *C. dubia* in laboratory dilution water) within the guidelines specified in the study plan (CH2MHILL 2001) and the EPA interim guidance document (EPA 1994a). This conclusion is supported by analyses presented in Attachment B to this report, and the detailed results provided in Appendices C and D.

Chemical Analyses

All analytical data for QA/QC blanks including bottle blanks, filter blanks, and method blanks showed that contamination was not introduced in sampling and analysis (Appendix B). Laboratory and site water spiked with copper and lead was measured for dissolved copper and lead before and after toxicity testing. Out of 786 samples analyzed as part of the WER bioassay tests, only 2 samples (0.3 percent) appeared to be anomalies and were removed from the dataset. Both data points were elevated initial dissolved measurements that were substantially higher than the total recoverable measurements (Appendix E). The first anomalous data point was observed in the highest laboratory copper solution for the Lander Street *C. dubia* test from Round 1; the initial dissolved measurement removed (15.4 µg/L) was more than twice the total recoverable measurement (6.4 µg/L). To calculate the dissolved LC_{50} for this test, only the final dissolved measurement was used (4.2 µg/L). Because this solution represented 100 percent mortality, the removal of this data point did not substantially alter the final LC_{50} value.

The second anomalous data point was observed in the mid-range laboratory copper solution for the Lander Street *C. dubia* test from Round 2; the initial dissolved measurement removed (12.5 µg/L) was more than five times higher than the total recoverable measurement (2.4 µg/L). To calculate the dissolved LC_{50} for this test, only the final dissolved measurement (1.1 µg/L) was used. Because this solution represented 50 percent mortality, the removal of this data point directly affected the final LC_{50} value. However, the range of concentrations in this particular dose-response curve ranged from 1.2 to 2.9 µg/L, so the change to the final LC_{50} value was negligible.

In almost all of the *H. azteca* toxicity tests, the concentration of dissolved lead was substantially lower at the end of testing in both the laboratory and site (mixed) samples (Appendix E). It is possible that the organisms accumulated lead during testing and this led to a decline in dissolved metals. To be conservative, for all of the *H. azteca* tests at both sites, only the initial dissolved metals concentrations were used to calculate dissolved LC_{50} values and WERs. Because this decision biased the LC_{50} value high for both the laboratory and site tests, the relative ratio between the toxicity endpoints was not affected substantially.

Conclusions

The WERs observed in this study show that the species tested (*C. dubia* and fathead minnow) are less sensitive to copper under site-specific conditions than under laboratory conditions. Because Idaho expresses its copper criterion as dissolved, the SSC for copper is calculated by multiplying the statewide copper WQC by the final dissolved WER of 2.578. This means that the proposed acute copper SSC (CMC) should be 23 µg/L[4] (8.856 µg/L × 2.578) and the chronic copper SSC (CCC) should be 16 µg/L (6.277 µg/L × 2.578) at 50 mg/L $CaCO_3$ hardness. These SSC would be protective of locally important species (such as rainbow trout) in the lower Boise River.

For lead, the WERs observed in this study show that the species tested (*C. dubia* and *H. azteca*) are also less sensitive to lead under site-specific conditions than under laboratory conditions. Because Idaho expresses its lead criterion as dissolved, the SSC for lead is calculated by multiplying the statewide lead WQC by the final dissolved WER of 2.049. This means that the proposed acute lead SSC (CMC) should be 62 µg/L (30.14 µg/L × 2.049) and the chronic lead SSC (CCC) should be 2.4 µg/L (1.174 µg/L × 2.049) at 50 mg/L $CaCO_3$ hardness. These SSC would be protective of locally important species (such as rainbow trout) in the lower Boise River.

Table 14 presents a summary of the current and proposed criteria for copper and lead.

TABLE 14
Example Current and Proposed Criteria for Copper and Lead (Hardness of 50 mg/L $CaCO_3$)

	Dissolved Copper	Dissolved Lead
Water-Effect Ratio (WER)	2.578	2.049
Acute		
Current	8.9 µg/L	30 µg/L
Proposed SSC	23 µg/L	62 µg/L
Chronic		
Current	6.3 µg/L	1.2 µg/L
Proposed SSC	16 µg/L	2.4 µg/L

Results from the study indicate combining the data from the Lander Street and West Boise WWTPs is appropriate. The site to which the proposed copper and lead WER should be applied will be determined through negotiations with DEQ and EPA.

[4] Consistent with 40 CFR 131.36, final criteria should be expressed to two significant digits.

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Reviewers included Chris Mebane, with the DEQ in Boise, Idaho; Lisa Macchio and Madonna Narvaez, with EPA Region 10 in Seattle, Washington; and Charles Stephan, with the EPA National Health and Environmental Effects Research Laboratory in Duluth, Minnesota. Additional review of the study design was provided by Stephan Bainter in EPA Region 6 in Dallas, Texas.

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Attachment A: Evaluation of Proposed Copper Criteria for Locally Important Species

At DEQ's request, the proposed SSC for copper were also evaluated to ensure that they are protective of locally important and sensitive species. Rainbow trout are being used in this analysis because they represent a relatively sensitive vertebrate in comparison to other salmonids, including brown trout or mountain whitefish (EPA 1999, Welch et al. 1998), which are other game fish present at the site. Although the rainbow trout found in the lower Boise River are primarily stocked adult fish, early life stage (ELS) data are used in the analysis because the ELS is more sensitive to toxicity caused by copper than adult fish and protection of ELS organisms provides a reasonable surrogate for protecting naturally reproducing populations of other salmonids.

Other studies have tested laboratory waters adjusted to match certain parameters of site waters. To compare these studies to the Boise WER study results, all toxicity values have been normalized to a hardness of 50 mg/L $CaCO_3$ using a pooled slope of 0.9422. The total recoverable species mean acute value (SMAV) for rainbow trout is 42.5 µg/L according to the copper criteria document (EPA 1984a). This rainbow trout SMAV is consistent with values summarized by Chapman (1999) for the Clark Fork site of 41.5 µg/L (EPA 1999).

The database Chapman compiled for EPA contains a summary of available copper toxicity data for rainbow trout. In addition, over 62 total recoverable and dissolved 96-hour WER tests were conducted by ENSR on rainbow trout for the Clark Fork River (EPA 1999). The ENSR tests were conducted on rainbow trout ranging between 29 and 87 days old, with weights less than 0.70 gram. Therefore, based on the weight of the fish it appears that the dataset developed by ENSR reflects a relatively young rainbow trout population and these toxicity values are summarized in Appendix F. Appendix F also contains toxicity values from Chapman's database for those tests conducted on organisms weighing less than 0.70 gram, as well as results from Marr et al. (1998) for tests conducted on juvenile species. All values have been normalized to a hardness of 50 mg/L $CaCO_3$ using a rainbow trout-specific slope of 0.6430 for total recoverable copper and 0.7524 for dissolved copper (the LC_{50} at 50mg/L $CaCO_3$ hardness = LC_{50} * ((50/hardness) ^{slope})). These slopes are based only on those tests that were conducted on ELS rainbow trout (defined as weighing between 0.07 and 0.71 gram) included in Appendix F. As shown in Figure A-1, the slopes for both total recoverable and dissolved copper have a higher correlation coefficient (r^2 = 0.4132 and 0.4922, respectively) than the pooled slope of 0.9422 (r^2 = 0.3042) from the national copper criteria document (EPA 1984a).

The geometric mean acute toxicity at 50 mg/L hardness for ELS rainbow trout in laboratory water is 32.0 µg/L (n=67) for total recoverable copper and 27.4 µg/L (n=70) for dissolved copper. However, these laboratory values do not take into consideration site-specific conditions, which is the major objective of this study. To estimate what the site-specific lethality concentrations would be to ELS rainbow trout, additional literature studies and data from this study have been evaluated.

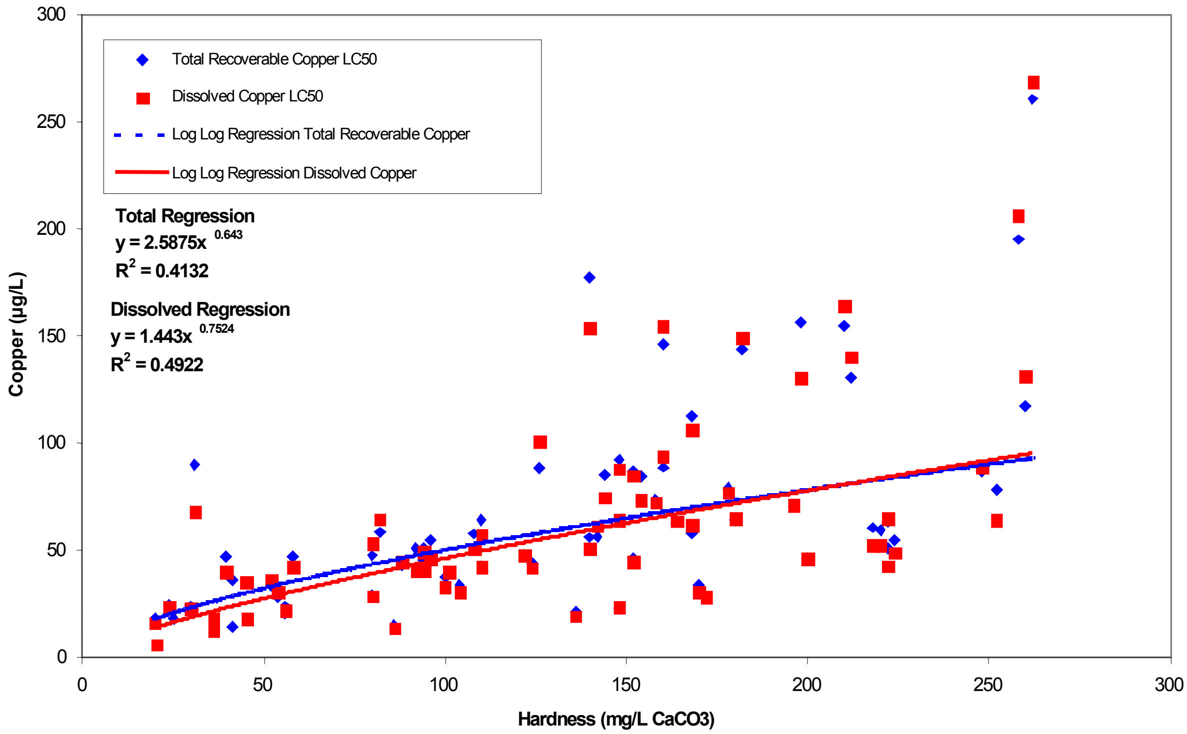

FIGURE A-1
Copper 96-Hour Toxicity Compared to Hardness for Juvenile Rainbow Trout (< 0.71 grams)

In other studies, a WER reflecting site-specific attenuation of copper toxicity has consistently been demonstrated. Brungs et al. (1992) reported that all eight copper WER studies (using five different species) had total recoverable WERs ranging between 1.0 and 15.3 (mean 5.4). At the Clark Fork River site, acute and chronic copper bioassays were conducted on three species (*C. dubia*, fathead minnow, and rainbow trout). The WERs obtained in the study ranged from 1.56 to greater than 25.6 for total recoverable copper and from 1.04 to 10.6 for dissolved copper (EPA 1999).

As described earlier, the Clark Fork studies specifically conducted on rainbow trout include more than 62 acute WER bioassays over a wide range of hardness values and flow conditions (EPA 1999). Based on these results, acute WERs specifically for rainbow trout ranged between 1.89 and 3.47 (mean 2.7) for total recoverable copper and 1.61 and 2.98 (mean 2.2) for dissolved copper (EPA 1999). These results are consistent with the St. Louis River in Minnesota, where a total recoverable WER of 3.2 was developed using rainbow trout (Brungs et al. 1992).

These studies suggest that it is reasonable to assume that a WER greater than 1.0 also exists for rainbow trout in the lower Boise River. In general, it is expected that a species with a high sensitivity to a metal will produce a relatively higher WER than a species with lower sensitivity. In fact, multiple species are partly tested to confirm the assumption that less sensitive organisms will usually give WERs that are lower than tests using sensitive organisms (EPA 1994a). The issue of whether sensitive species produce higher or lower WERs than less sensitive species has been evaluated by Diamond et al. (1997). Diamond and colleagues found slightly higher WERs for copper in fathead minnow (11.5) than in *C. dubia*

(7.4). However, Diamond also found that these copper WERs were not statistically different (p greater than 0.05) from one another. Other studies conducted in the early phases of the Clark Fork River site found that species sensitivity did not appear to correspond to expected WERs, as rainbow trout produced both higher and lower copper WERs than the more sensitive *C. dubia* (ENSR 1995, 1996).

Despite uncertainties in other studies with different receiving waters and effluents, results from the lower Boise River study support the conclusion that WERs associated with a more sensitive species are higher than WERs associated with a less sensitive species. During simultaneous testing in Round 3 (the case with the highest copper bioavailability), the combined WER obtained with more sensitive *C. dubia* (9.191) was more than 4 times larger than the less sensitive fathead minnow WER (2.154). To estimate the site-specific WER for rainbow trout, which are more sensitive than fathead minnow and less sensitive than *C. dubia*, data from this study are evaluated.

In the most recent guidance on streamlined WERs, EPA has published a total recoverable SMAV of 12.5 µg/L for *C. dubia* at 50 mg/L $CaCO_3$ hardness (EPA 2001). For comparison purposes, the total recoverable SMAV for rainbow trout is 42.5 µg/L and the total recoverable SMAV for fathead minnow is 115 µg/L according to the copper criteria document (EPA 1984a). It is reasonable to assume that a site-specific WER for rainbow trout would fall between 2.154 and 9.191 because rainbow trout are more sensitive than fathead minnow and less sensitive than *C. dubia.* Based on the assumption that less sensitive organisms will usually give WERs that are lower than tests using sensitive organisms (which is supported by results from this study), it may be conservative to assume that the dissolved WER for rainbow trout is equal to the dissolved WER of 2.154 for fathead minnow. Alternatively, this may be the best estimate of a dissolved WER for rainbow trout that is possible with existing data, because it is similar to the Clark Fork dissolved WER of 2.2 for rainbow trout and the assumptions of higher WERs for more sensitive species have not always been empirically supported (as discussed earlier).

To estimate the site-specific acute toxicity of copper to ELS rainbow trout, the mean acute laboratory value normalized to 50 mg/L $CaCO_3$ hardness (27.4 µg/L) is multiplied by the dissolved fathead minnow WER (2.154). This calculation results in an estimated site-specific dissolved acute value for ELS rainbow trout of 59.0 µg/L. This value is then compared to the current acute criterion (8.86 µg/L), which is based on taking the final acute value divided by two to represent zero mortality (EPA 1984b; Stephan et. al. 1985). Such an approach is consistent with the Clark Fork dataset for rainbow trout, where a factor of 2 was used to extrapolate from an LC_{50} to an LC_0 (EPA 1999). ***Thus, the final site-specific dissolved copper concentration that would be expected to cause zero mortality to ELS rainbow trout is estimated at 29.5 µg/L*** (59.0 µg/L divided by 2).

Attachment B: Comparison of Test Results in Laboratory Water with National Datasets

Ceriodaphnia dubia (Copper)

The LC_{50} values for the reference toxicant and laboratory tests with *C. dubia* for copper were apparently lower than the LC_{50} values for the group of tests used by EPA (EPA 2001). Data from this study were compared statistically to the *C. dubia* results used by EPA in the March 2001 streamlined WER dataset (EPA 2001).

Figure B-1 shows a graph of the LC50 values versus the hardness used in the EPA and SF Analytical tests.

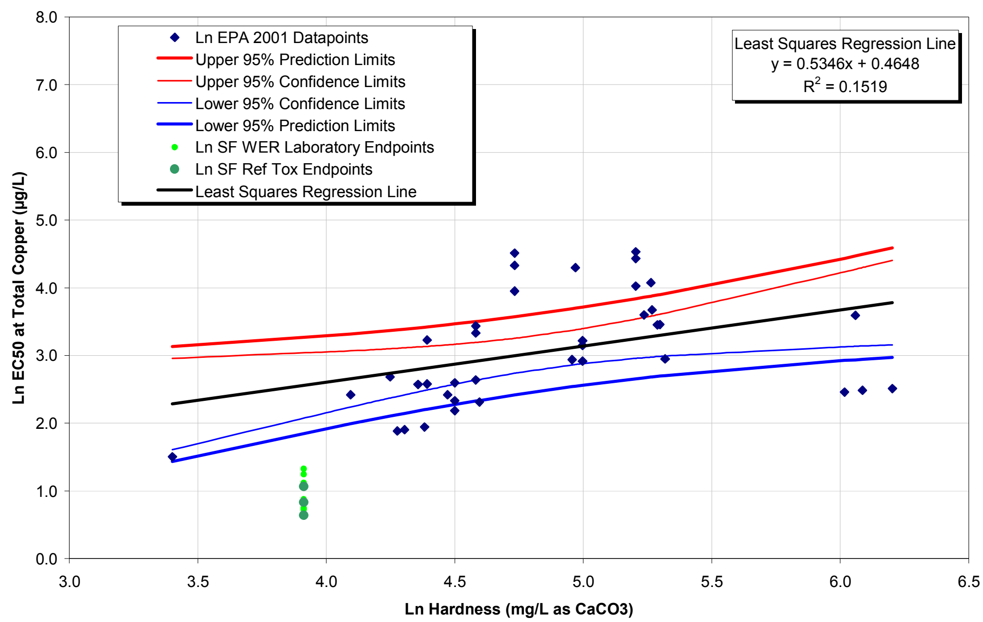

FIGURE B-1
Regression Analysis of Hardness Compared to LC_{50} Values for Total Recoverable Copper for *C. dubia* (k=9)

This figure shows that the geometric mean endpoint value observed in this study (2.6 µg/L and 0.95 on a natural log scale) is not within a factor of 1.5 (Section I.5.a; EPA 1994a) of the geometric mean endpoints reported by other laboratories adjusted for hardness (12.5 µg/L [EPA 2001] and 2.52 on a natural log scale). In addition to comparing mean values between the two datasets, 95 percent confidence and prediction limits were calculated according to the methods outlined in Sokal and Rohlf (1969).

The prediction limits in Figure B-1 was plotted using a value of k=9, where k is the number of values in a new dataset that is to be compared with an old dataset. That is, prediction limits are based on statistical parameters associated with the 38 EPA data points and setting k=1 provides an indication of whether the next sample point would fall into these prediction limits. Setting k=n provides an indication of whether the mean of the next n samples would fall into these prediction limits. In this analysis, k=9 because there are nine data points in the SF dataset (six WER bioassays and three reference toxicant tests). The mean value for the SF endpoints (on the natural log scale, this equals 0.95) falls below the lowest 95 percent prediction limit (1.86 on the natural log scale) at a hardness of 50 mg/L as $CaCO_3$ (3.91 on the natural log scale).

Alternatively, when k is set equal to 1 to evaluate each SF endpoint independently, the 95 percent prediction limits move farther away from the 95 percent confidence limits, as shown in Figure B-2.

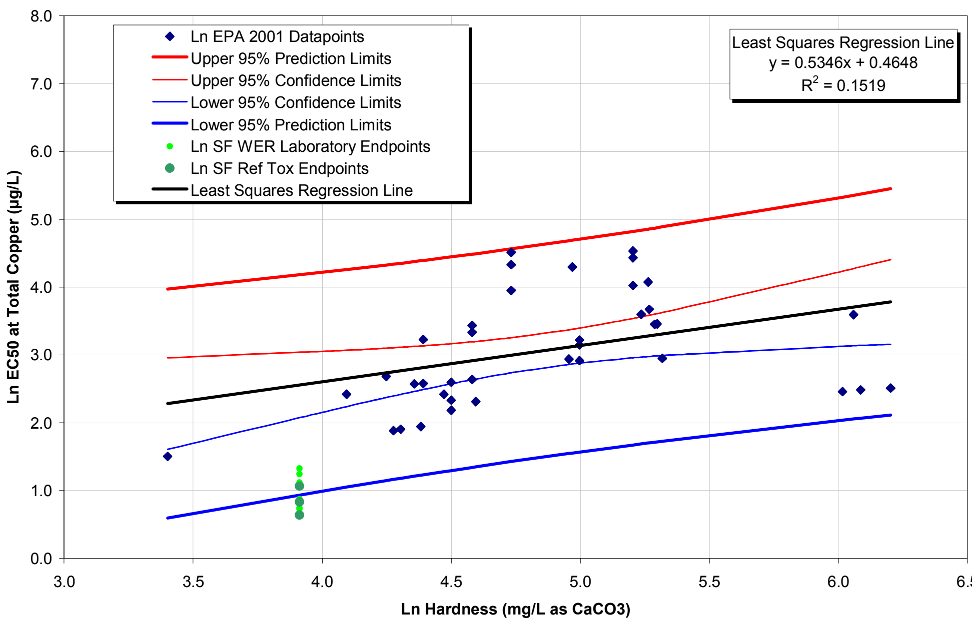

FIGURE B-2
Regression Analysis of Hardness Compared to LC_{50} Values for Total Recoverable Copper for *C. dubia* (k=1)

In comparison against 95 percent prediction limits calculated using k=1, the mean value for the SF endpoints (0.95 on the natural log scale) falls within the lowest 95 percent prediction limit of 0.94 at a hardness of 50 mg/L as $CaCO_3$. However, 33 percent of all of the LC_{50} values in the SF Lab Data fall outside of the 95 percent prediction limits for *C. dubia* (these data include two reference toxicant tests and one WER test), whereas only 5 percent of the dataset should fall outside the 95 percent prediction limits calculated using k=1.

Analysis using k=9 and analysis using k=1 both show that the measured toxicity values from this study are lower than the other reported toxicity value adjusted for hardness. Use of prediction limits assumes that the variances of the two datasets are the same, but in this case the variances clearly are not the same. Use of a more appropriate variance would make the datasets look even more different. Conceptually, the easiest way to do a more appropriate analysis would be to do a t-test for unequal sample sizes and unequal variances in a regression setting, but this is unnecessary because the two datasets are clearly different.

The reasons why the SF measured endpoints were lower than other reported values could range from using particularly sensitive organisms to an unsuspected toxicant. SF Analytical has conducted hundreds of other bioassays nationwide without concern. SF conducts other bioassays using laboratory water that is typically (but not always) reconstituted to match a specific hardness concentration. In this study, the laboratory water was reconstituted to match the hardness of the site receiving water, as well as the receiving water ratio of Ca:Mg (as specified in the DEQ- and EPA-approved study plan [CH2MHILL 2001]). In addition, SF Analytical is certified by the state of Wisconsin and have always passed annual inspections without comment. They also participate in and have always passed the EPA annual round-robin blind toxicity tests. Therefore, we have no reason to suspect any bioassay laboratory or measurement errors could have contributed to the lower values. Although the chemical measurements of the laboratory water used for this study do not suggest that this laboratory water contained any unusual chemical or physical parameters, a full analysis of toxic chemicals was not performed. Thus, it is difficult to surmise why our measured values are lower than other reported values adjusted for hardness.

As discussed previously, because the *C. dubia* laboratory test results were lower than those in the national dataset , the *C. Dubia* test results in site water were compared to the *C. dubia* values in the national dataset for the derivation of the final WER value for copper as specified in the EPA streamlined WER guidance (EPA 2001).

Fathead Minnow (Copper)

The acute reference toxicant values from this study were all within a factor of 3 of the laboratory toxicity test values for acute toxicity during the WER testing. In addition, as shown in Figure B-3, the geometric mean endpoint value observed in this study (84.8 µg/L) is within a factor of 1.5 of the geometric mean endpoints reported by other laboratories adjusted for hardness (100.5 µg/L; EPA 1984).

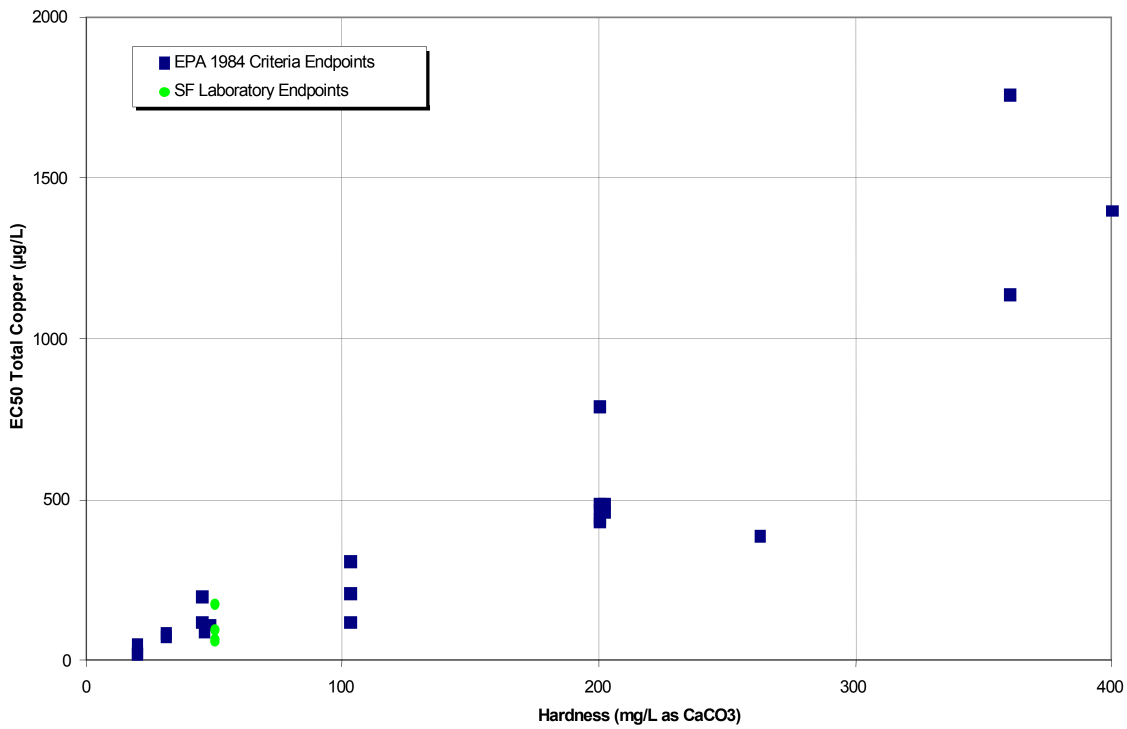

FIGURE B-3
Regression Analysis of Hardness Compared to LC_{50} Values for Total Recoverable Copper for Fathead Minnow

Ceriodaphnia dubia (Lead)

The acute reference toxicant values from this study were all within a factor of 3 of the laboratory toxicity test values for acute toxicity during the WER testing. As shown in Figure B-4, although the geometric mean endpoint value observed in this study (197 µg/L) is slightly above the 1.5-factor of the geometric mean endpoints reported by other laboratories adjusted for hardness (98.1 µg/L; EPA 1998), the *C. dubia* values for lead for the laboratory tests appear to be acceptable.

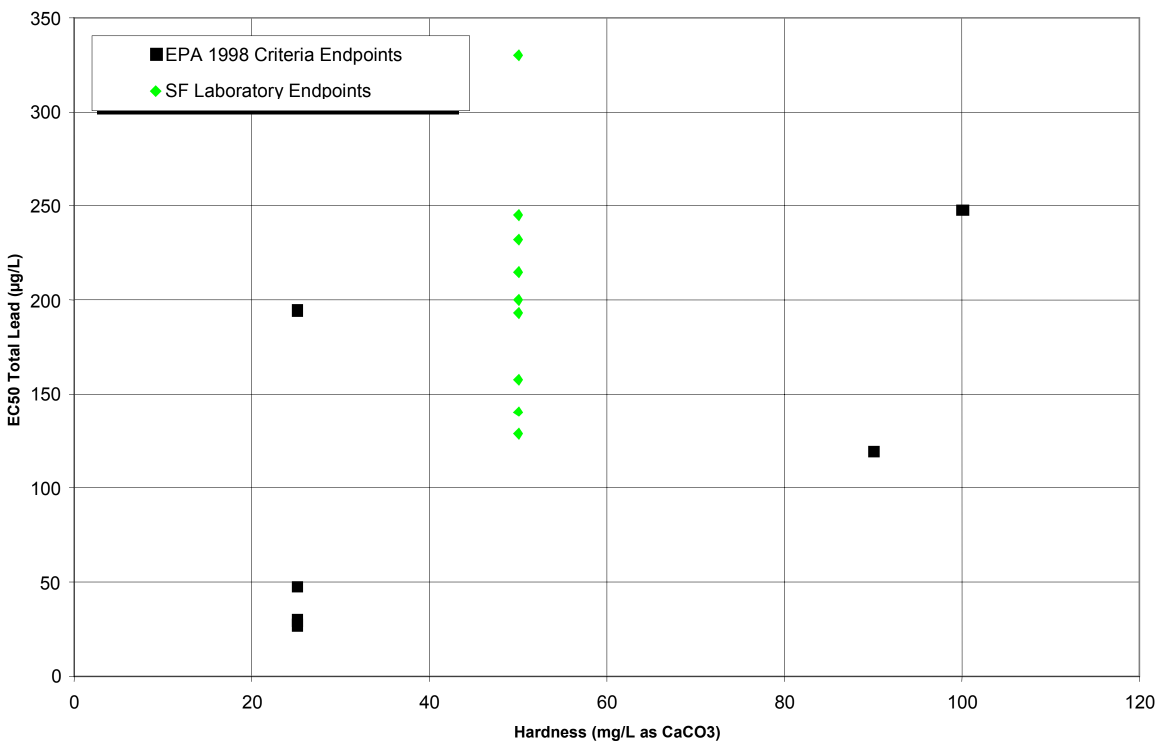

FIGURE B-4
Regression Analysis of Hardness Compared to LC_{50} Values for Total Recoverable Lead for *C. dubia*

Hyallela azteca (Lead)

The acute reference toxicant LC_{50} values from this study were within a factor of 3 of the LC_{50} values for WER test with laboratory water.

The draft EPA (1998) lead criteria document lists the total recoverable SMAV for *H. azteca* as less than 18.8 µg/L at 50 mg/L hardness. This is based on the results of one toxicity test reported by Phipps (1995). For this study we observed a geometric mean of all the acute values of be 45.8 µg/L for total recoverable lead. Because five tests in this study (including three reference toxicant tests and two site tests) showed relatively consistent results, the results from this study are believed to be representative of the toxicity of lead to *H. azteca*.