Aquatic Impact Assessment Related to Current and Future Zinc, Cadmium, and Sulphate Concentrations at Faro Mine, Yukon

Report Prepared for:

Assessment and Abandoned Mines Branch
Energy, Mines and Resources
Government of Yukon
Whitehorse, Yukon

Report Prepared by:

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February 2010

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1.0 INTRODUCTION

1.1 Background

The Faro Mine complex, near Faro, Yukon, includes two sites: the Faro Mine and Mill (Faro site) and Vangorda/Grum Mines (Vangorda site), which are located approximately 12 km apart (Figure 1.1). The complex was formerly owned by the Anvil Range Mining Corporation and produced lead and zinc concentrates to be extracted for lead, zinc, silver, and gold. The Faro site was mined between 1969 and 1992, while the Vangorda site was developed and mined between 1986 and 1998. Milling continued at Faro until April 1998, when all operations were terminated due to poor economic circumstances and the site went into receivership. Until early 2009, management of the mine property was under the direction of Deloitte and Touche Inc., acting as the court appointed Interim Receiver. Site Care and Maintenance responsibilities were transferred in early 2009 to a contractor acting on behalf of the Yukon Government.

The Yukon government and its consultants, working with the federal government, Selkirk First Nation, and Ross River Dena Council, have been preparing a comprehensive closure plan for the abandoned Faro Mine complex. Before the closure plan can be implemented, it will be subject to regulatory assessment and approval processes carried out through the Yukon Environmental and Socio-Economic Assessment Board under the *Yukon Environmental and Socio-Economic Assessment Act* (YESAA). A Water License, issued under the *Waters Act* by the Yukon Water Board, will also be required.

Technical studies conducted at the site indicate that acidification and leaching processes have the potential, depending on the options implemented for mine closure, to result in substantial increases in metal loadings to surface waters downstream of the Faro Mine complex over the next several to many decades. In particular, zinc, cadmium and sulphate concentrations were identified as substances of potential concern. Minnow Environmental Inc. (Minnow) was asked to conduct a preliminary assessment of the potential for predicted concentrations to impact biota residing in surface waters downstream of the mine based on toxicity data presented in the scientific literature.

1.2 Project Objectives and Overview

Toxicity data for zinc, cadmium, and sulphate were summarized and compared to current and predicted surface water quality downstream of the Faro Mine to identify potential impacts to aquatic biota. Assessment of potential impacts to biota took into account:

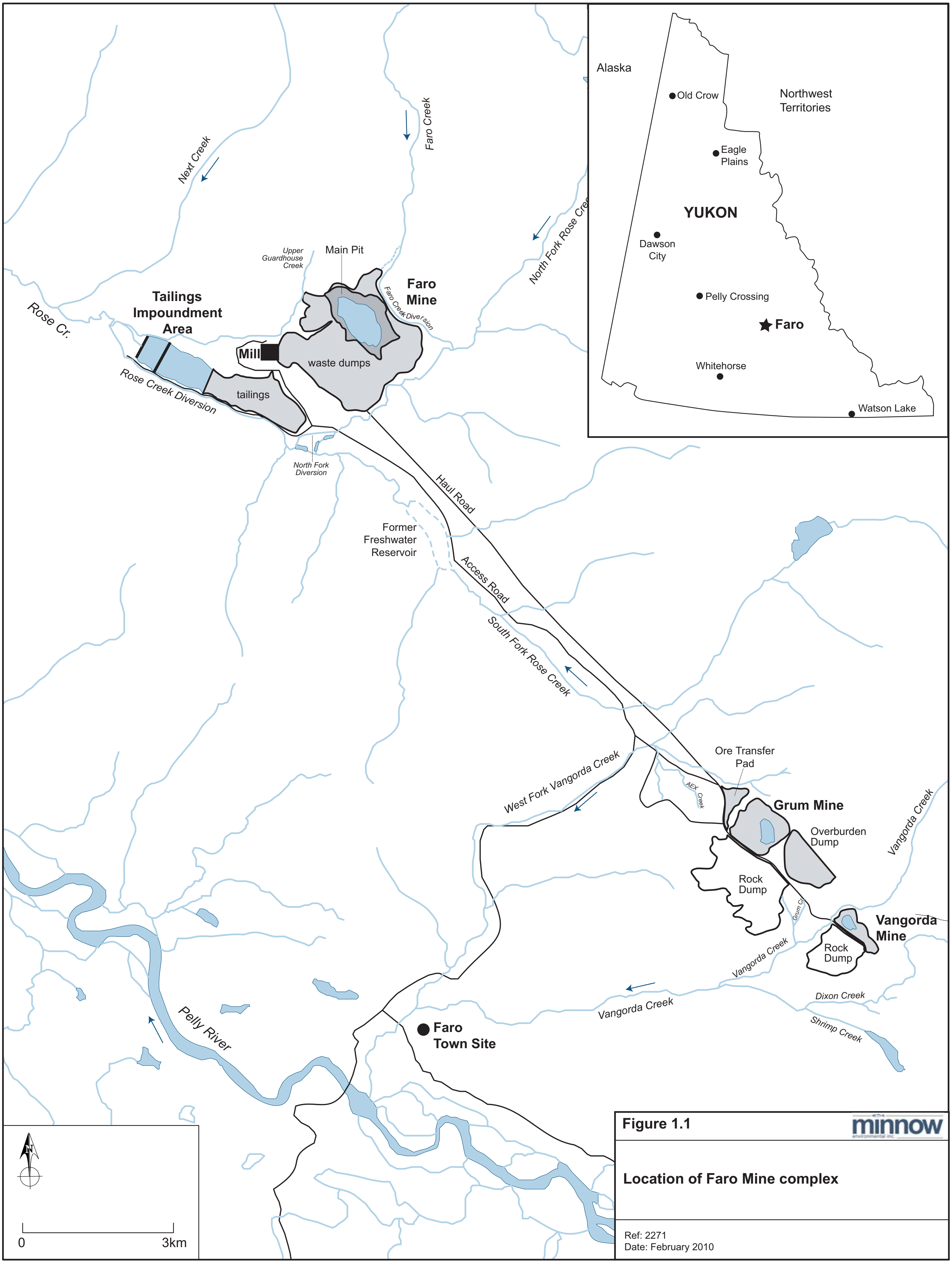

Figure 1.1

Location of Faro Mine complex

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- median and maximum annual concentrations expected to occur following mine closure;
- seasonal variations in water hardness versus metal and sulphate concentrations to determine the time of year when aquatic impacts are likely to be greatest;
- the relevance of the test species discussed in the literature to those found near the Faro mine; and
- results of toxicity tests previously conducted on water samples collected at the Faro Mine complex.

1.3 Document Organization

Section 2.0 presents the methods used in the evaluation of data for this project. Section 3.0 summarizes toxicity data for zinc, cadmium, and sulphate presented in the scientific literature and compares these values to recent and predicted water quality concentrations for aquatic environments downstream of the Faro Mine. Conclusions are presented in Section 4.0. References cited throughout the document are presented in Section 5.0

2.0 METHODS

2.1 Recent Water Quality

Site water quality data for the period 2005-2007[1], inclusive, were provided to Minnow by AECOM, Whitehorse YT, and included water hardness, zinc, cadmium and sulphate concentrations measured at stations V8, X2, X14, R2, R3, R4, R5, and A1 (Figure 2.1). Insufficient data (n≤10) were available for R2, R5 and A1 for the 2005-07 time period, so data to mid-2009 were used to augment the data sets for these locations. Also, much of the reported data for cadmium were excluded from the evaluation because concentrations were reported as less than the detection limit and the detection limit (0.0002) was above the Canadian Water Quality Guideline for cadmium (e.g., 0.00003 mg/L at water hardness of 100 mg/L; CCME 1999). To obtain a reasonable sample size to support the evaluation, cadmium data available to mid-2009 were also downloaded for all stations.

Summary statistics were computed for each substance at each monitoring station, including minimum, maximum, mean, median, and standard deviation (Appendix A).

2.2 Predicted Water Quality

"Best estimate" water quality predictions (GEEC 2010) were provided for the 185-year period beginning in 2027, which is the year after which site remediation and closure is expected to be completed. Predicted annual median and maximum values[2] were compared to concentrations measured in recent years and to toxicity data available in the scientific literature for zinc, cadmium, and sulphate to assess potential effects of mine releases of these substances on biota inhabiting downstream aquatic environments.

2.3 Toxicity Data Sources and Organization

Recently-prepared toxicity data summaries for zinc and cadmium, along with copies of much of the source literature were obtained from Environment Canada's Guidelines and Standards Office in Gatineau Quebec, augmented by relevant scientific literature from Minnow's in-house files. The source literature was reviewed to verify the accuracy of the data sets provided and allow for clarification of test conditions. Toxicity data for sulphate were initially summarized from Singleton (2000), but a number of the journal articles cited

[1] This period was selected to be consistent with the data range used in other projects supporting Faro Mine closure, although more recent data were also included for some aspects of this project to improve sample sizes. These exceptions have been noted, where applicable.

[2] Median values reported in this study represent the median of predicted monthly median values for the stated time period. Maximum values represent the maximum of predicted monthly maximum values for the same time period.

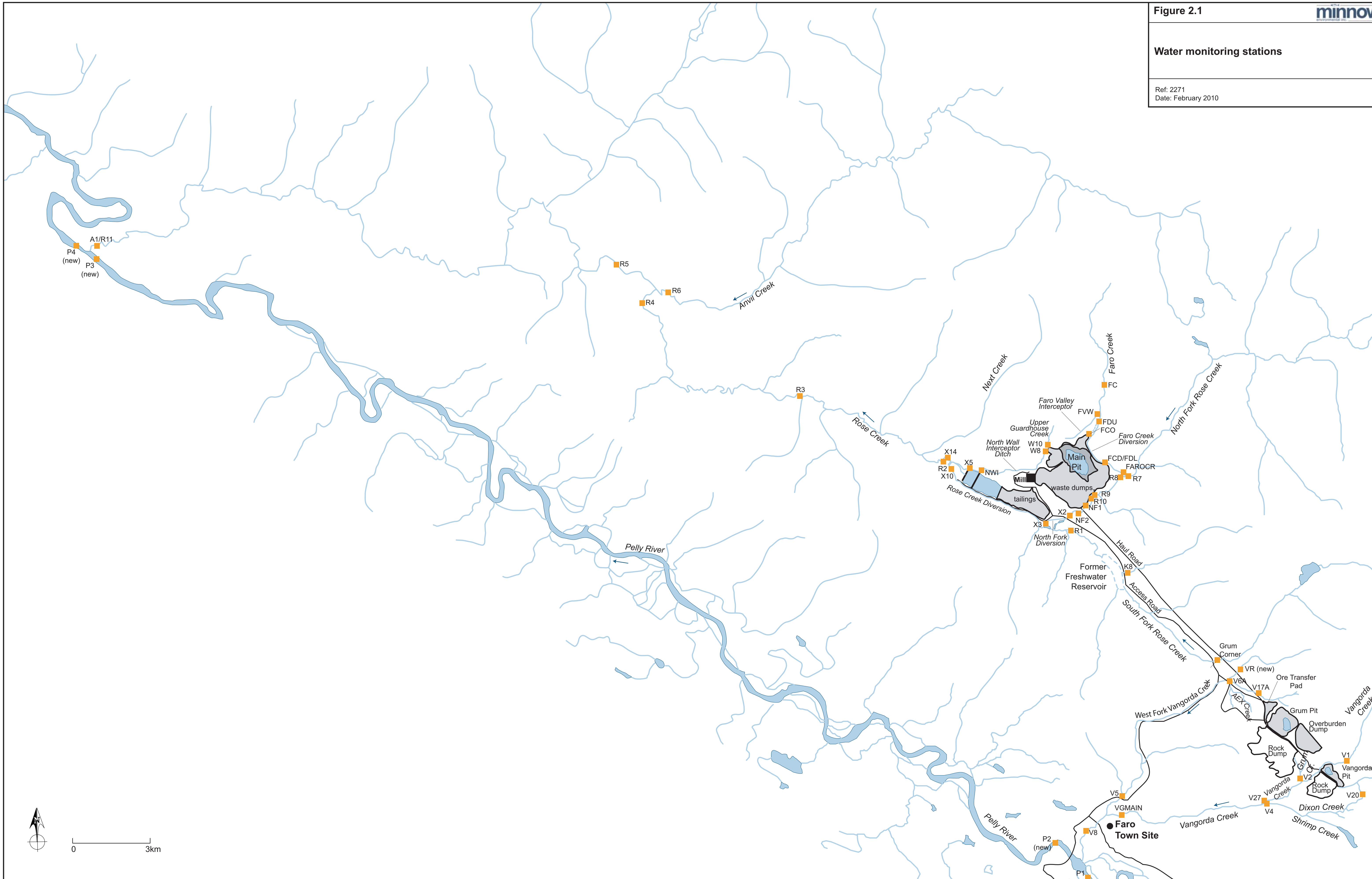

Figure 2.1

Water monitoring stations

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Date: February 2010

by Singleton were also obtained and reviewed in order to verify accuracy of the data reported. Additional, relevant articles published after Singleton (2000) were obtained and used to augment the data set. The reviews of source literature resulted in some minor modifications of the original data sets.

Raw data tables presented details of each toxicity test, including results of replicate exposures within studies, if available. The tabulated information included species common and scientific name, test duration, test endpoint, observed effect concentration, test conditions (e.g., hardness, pH, etc., if reported) and source (author, year). Toxicity test data were distinguished as short-term versus long-term exposures. Depending on the species and life-stage tested, short-term exposures were defined as less than one (algae), four (invertebrates and larval fish), or seven days (older fish), consistent with current Environment Canada protocols (Environment Canada 2008, 2009). Long-term exposure data were considered most relevant for assessing potential effects associated with chronic exposure to mine-related contaminants at Faro, so toxicity evaluations for cadmium and zinc focussed primarily on long-term exposure data. For sulphate, the aquatic toxicity data set was more limited, so short-term exposure data were also included in the evaluation (based on LC50 endpoints) to ensure data were considered for the broadest possible range of species. Data for exposures to potassium sulphate salts were excluded from the evaluation because the potassium ion is more toxic than the sulphate ion (Mount and Gulley 1992).

2.4 Relationships with Hardness

The toxicities of zinc, cadmium, and sulphate are influenced by various water quality factors, of which the best characterized is hardness (Singleton 2000, Minnow 2008, Environment Canada 2008, 2009). In order to rank the relative sensitivities of different aquatic species to these contaminants, it was necessary to convert reported effect concentrations to a common water hardness. A hardness of 100 mg L^{-1} as $CaCO_3$ was selected as the basis for comparison, because water hardness downstream of the Faro Mine is rarely lower than this level. However, effects at other hardnesses were also evaluated (see below).

Hardness-toxicity relationships were first defined for individual species for which adequate data were available. This was done by examining the raw data to identify toxicity tests for which the hardness of the exposure water was reported and identifying species for which there were data for the same or similar endpoints over a range of exposure water hardness levels (>2-fold range), including at least one exposure with water hardness of at least 100 mg/L. For zinc, only tests conducted at pH ≥ 7.4 were included to minimize the variability associated with this potentially confounding factor (more data were available for a basic than neutral-acidic range of exposure pH). If there were replicate test results within a study for the same endpoint at the same or similar water hardness, geometric mean hardness and effect concentrations were computed before using the data to define the hardness-toxicity relationship for the substance.

The resulting data were then plotted for each species based on a regression of natural logarithm (Ln) of toxicant concentration as the dependent variable against Ln hardness as the independent variable. This yielded the species-specific slope for the hardness-toxicity relationship. For all three substances (Cd, Zn, sulphate), there were sufficient data to derive a slope for at least one plant/alga, invertebrate, and fish species.

For each contaminant, the slopes for the hardness-toxicity relationship were tested for differences among species and, if not different, the slopes were combined to generate an average slope. Only in the case of short-term exposure data for sulphate was a significant difference found ($p<0.05$; Appendix Table E.4). After consideration of the data and potential implications of applying different slopes for different species or groups of species, a decision was made to generate a combined slope (including short- and long-term exposure data). This recognized that the range of slopes for short- versus long-term exposure data overlapped, there were no differences in slope that could be confidently ascribed to particular species or groups, and this approach would ensure better consistency with respect to data handling for all three contaminants.

To assess relative species sensitivity, the lowest toxic effect concentration corresponding to an exposure hardness of 100 mg/L was identified for each study and species. For studies not including an exposure hardness of 100 mg/L, the toxic effect concentration for each study-species combination was adjusted to an exposure hardness of 100 mg/L based on the combined slope for the hardness-toxicity relationship. The lowest value for each species (at hardness of 100 mg/L) was then identified and used to rank all species in terms of relative sensitivity. In cases where there were both effect (e.g., EC10, IC25, maximum acceptable toxicant concentration [MATC], etc.) and no-effect (NOEC) endpoints reported, the lowest effect concentration was selected.

For species for which the original test hardness was reported, the same slope factors described above were also used to estimate toxicity at other water hardness values (than 100 mg/L). If test hardness was not reported, an adjustment could not be made and the same reported effect concentration for the species was assumed for all water hardnesses.

2.5 Data Evaluation

Recent and predicted water concentrations for each contaminant at key locations downstream from the Faro site were compared to the toxic threshold concentrations for different aquatic species at different water hardnesses to identify species that may be adversely affected under different water hardness conditions. The evaluation considered how zinc, cadmium and sulphate concentrations vary relative to hardness levels and seasonally as well as how these relationships may change in the future. Taken together this information was used to evaluate current or future impacts associated with mine-related exposures of aquatic biota to zinc, cadmium, and sulphate.

3.0 RESULTS

3.1 Water Hardness

3.1.1 Recent and Predicted Concentrations

Median water hardness has ranged between approximately 100-300 mg/L at surface water stations downstream of the Faro Mine complex (Table 3.1). Of the stations shown in Table 3.1, the lowest water hardness has been observed at V27 on Vangorda Creek. Maximum hardness was highest at X14, immediately downstream of the Faro Mine tailings areas, although median values downstream of the Vangorda site (V8) have generally been higher than at X14 (Table 3.1).

After mine closure, median water hardness will continue to be close to 200 mg/L at all locations (Table 3.2). Post-closure maxima at V27 and X14 (hardness > 200 mg/L) are expected occur during summer months (July- September) with lower water hardness (<200 mg/L) during other months (Figures 3.1 and 3.2).

3.1.2 Effects on Biota

As noted in subsequent sections, the toxicities of zinc, cadmium, and sulphate are modified by water hardness, with greatest toxicity from these substances typically being observed at lowest water hardness levels. Therefore, potential impacts to biota inhabiting the surface water environments downstream of the Faro Mine are dependent on the simultaneous relative concentration of each substance and water hardness. The implications of this with respect to the toxicity of zinc, cadmium, and sulphate are discussed in subsequent sections.

Potential direct effects of very elevated hardness are difficult to estimate because this variable reflects the combined concentrations of both magnesium and calcium in water. Of these two ions, magnesium is relatively more toxic than calcium, but concentrations of magnesium alone would likely need to be more than 500 mg/L to elicit toxicity among fish and invertebrates (Mount and Gulley 1992). This is an order of magnitude higher than the maximum concentrations of magnesium previously observed downstream of X14 (Minnow 2007) and is well above maximum total hardness values (which will reflect both Mg and Ca ions) predicted after closure (Table 3.2). Therefore, hardness itself is not expected to cause adverse effects on biota downstream of the Faro mine.

Table 3.1: Summary of recent (2005-07[a]) hardness, zinc, cadmium, and sulphate concentrations near Faro Mine, Yukon

Substance	Location	Station	Period	Number of Samples	Concentration (mg/L)		
					Median	Minimum	Maximum
Hardness	Near field Vangorda Creek	V27	'05 - '07	12	97	17	209
	Vangorda Creek below confluence of east and west branches	V8	'05 - '07	37	293	112	449
	Pelly River downstream of Vangorda Creek	P2	'07 - '09	18	189	95	225
	Rose creek downstream of Faro tailings area	X14	'05 - '07	93	175	54	812
	Mouth of Rose Creek at Anvil Creek	R4	'05 - '07	10	199	117	262
	Mouth of Anvil Creek at Pelly River	A1	'07 - '09	17	165	68	224
	Pelly River downstream of Anvil Creek	P4	'07 - '09	18	180	104	216
Zinc	Near field Vangorda Creek	V27	'05 - '07	13	0.0257	0.0160	0.0318
	Vangorda Creek below confluence of east and west branches	V8	'05 - '07	39	0.0150	0.0070	0.0640
	Pelly River downstream of Vangorda Creek	P2	'07 - '09	18	0.0156	0.0001	0.0401
	Rose creek downstream of Faro tailings area	X14	'05 - '07	93	0.0330	0.0110	0.2500
	Mouth of Rose Creek at Anvil Creek	R4	'05 - '07	10	0.0126	0.0025	0.0250
	Mouth of Anvil Creek at Pelly River	A1	'07 - '09	17	0.0046	0.0001	0.0238
	Pelly River downstream of Anvil Creek	P4	'07 - '09	18	0.0134	0.0001	0.0458
Cadmium	Near field Vangorda Creek	V27	'05 - '09	15	0.000068	0.00004	0.00044
	Vangorda Creek below confluence of east and west branches	V8	'05 - '09	7	-[b]	-[b]	-[b]
	Pelly River downstream of Vangorda Creek	P2	'07 - '09	18	0.000175	0.000053	0.000505
	Rose creek downstream of Faro tailings area	X14	'05 - '09	30	0.000062	0.000016	0.000300
	Mouth of Rose Creek at Anvil Creek	R4	'05 - '09	20	0.000028	0.000007	0.000139
	Mouth of Anvil Creek at Pelly River	A1	'07 - '09	17	0.000025	0.000006	0.000170
	Pelly River downstream of Anvil Creek	P4	'07 - '09	18	0.000133	0.000033	0.000634
Sulphate	Near field Vangorda Creek	V27	'05 - '07	13	50	9	106
	Vangorda Creek below confluence of east and west branches	V8	'05 - '07	38	120	33	312
	Pelly River downstream of Vangorda Creek	P2	'07 - '09	18	58	120	320
	Rose creek downstream of Faro tailings area	X14	'05 - '07	89	99	17	704
	Mouth of Rose Creek at Anvil Creek	R4	'05 - '07	10	80	26	127
	Mouth of Anvil Creek at Pelly River	A1	'07 - '09	17	44	18	88
	Pelly River downstream of Anvil Creek	P4	'07 - '09	18	54	29	69

[a] Except in cases where sample size was too low (n < 10) because of infrequent sampling or poor method detection limits, in which case 2008 and 2009 data were included

[b] Too few data (n=7) to compute meaningful summary statistics

Table 3.2: Predicted concentrations over 200 years following closure in 2026 based on seasonal discharge of treated effluent.

Contaminant	Watershed	Location	Concentration (mg/L)					
			Initial (2027-2036)			Long Term (2027-2212)		
			Median	Minimum	Maximum	Median	Minimum	Maximum
Hardness	Vangorda Creek Drainage	V27	175	169	220	175	169	223
		V8	166	162	186	166	162	187
		P2	217	217	217	217	217	217
	Rose-Anvil Creek Drainage	X14	157	156	237	157	156	242
		R4	157	156	214	157	156	218
		A1	156	156	177	156	156	179
		P4	214	214	215	214	214	215
Zinc	Vangorda Creek Drainage	V27	0.076	0.037	0.195	0.084	0.037	0.528
		V8	0.044	0.026	0.100	0.052	0.026	0.427
		P2	0.023	0.023	0.023	0.023	0.023	0.025
	Rose-Anvil Creek Drainage	X14	0.088	0.023	0.457	0.113	0.023	0.994
		R4	0.068	0.021	0.368	0.088	0.021	0.797
		A1	0.035	0.018	0.170	0.042	0.018	0.361
		P4	0.024	0.023	0.030	0.024	0.023	0.038
Cadmium	Vangorda Creek Drainage	V27	0.00013	0.00006	0.00032	0.00017	0.00006	0.00055
		V8	0.00008	0.00005	0.00017	0.00012	0.00005	0.00045
		P2	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021
	Rose-Anvil Creek Drainage	X14	0.00007	0.00005	0.00041	0.00022	0.00005	0.00049
		R4	0.00006	0.00004	0.00031	0.00017	0.00004	0.00040
		A1	0.00005	0.00004	0.00014	0.00009	0.00004	0.00020
		P4	0.00020	0.00020	0.00021	0.00020	0.00020	0.00021
Sulphate	Vangorda Creek Drainage	V27	38	35	100	39	35	126
		V8	29	27	58	29	27	69
		P2	68	68	68	68	68	68
	Rose-Anvil Creek Drainage	X14	22	21	52	23	20	162
		R4	22	20	43	22	20	122
		A1	21	20	29	21	20	57
		P4	66	65	67	66	65	67

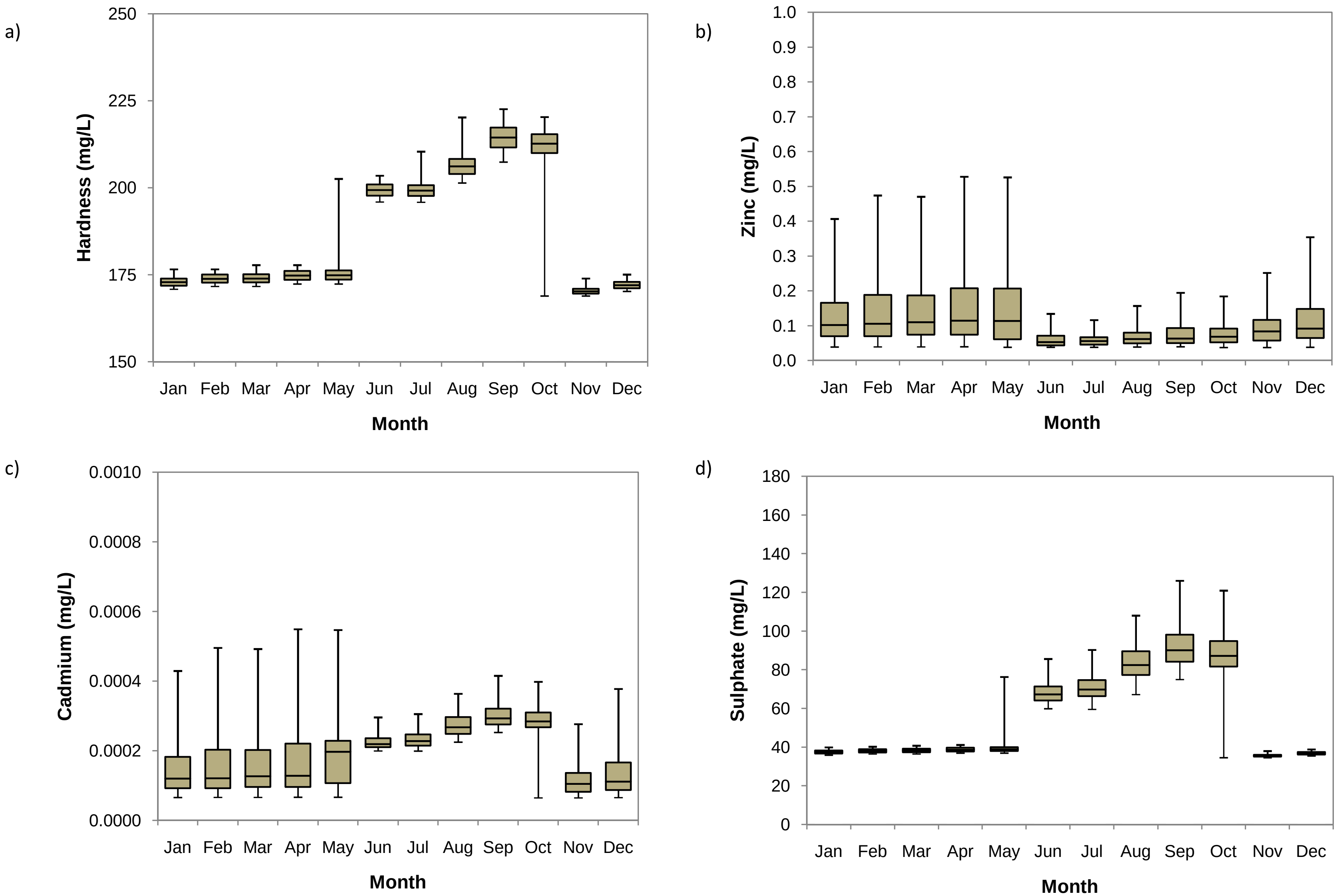

Figure 3.1: Predicted monthly zinc, cadmium, sulphate and hardness concentrations at V27, 2027-2212. "Boxes" represent 25th and 75th percentiles with solid lines within boxes representing median values. "Whiskers" represent minimum and maximum values. Data for the immediate post-closure period (2027 - 2036) are presented in Appendix Figure A.1.

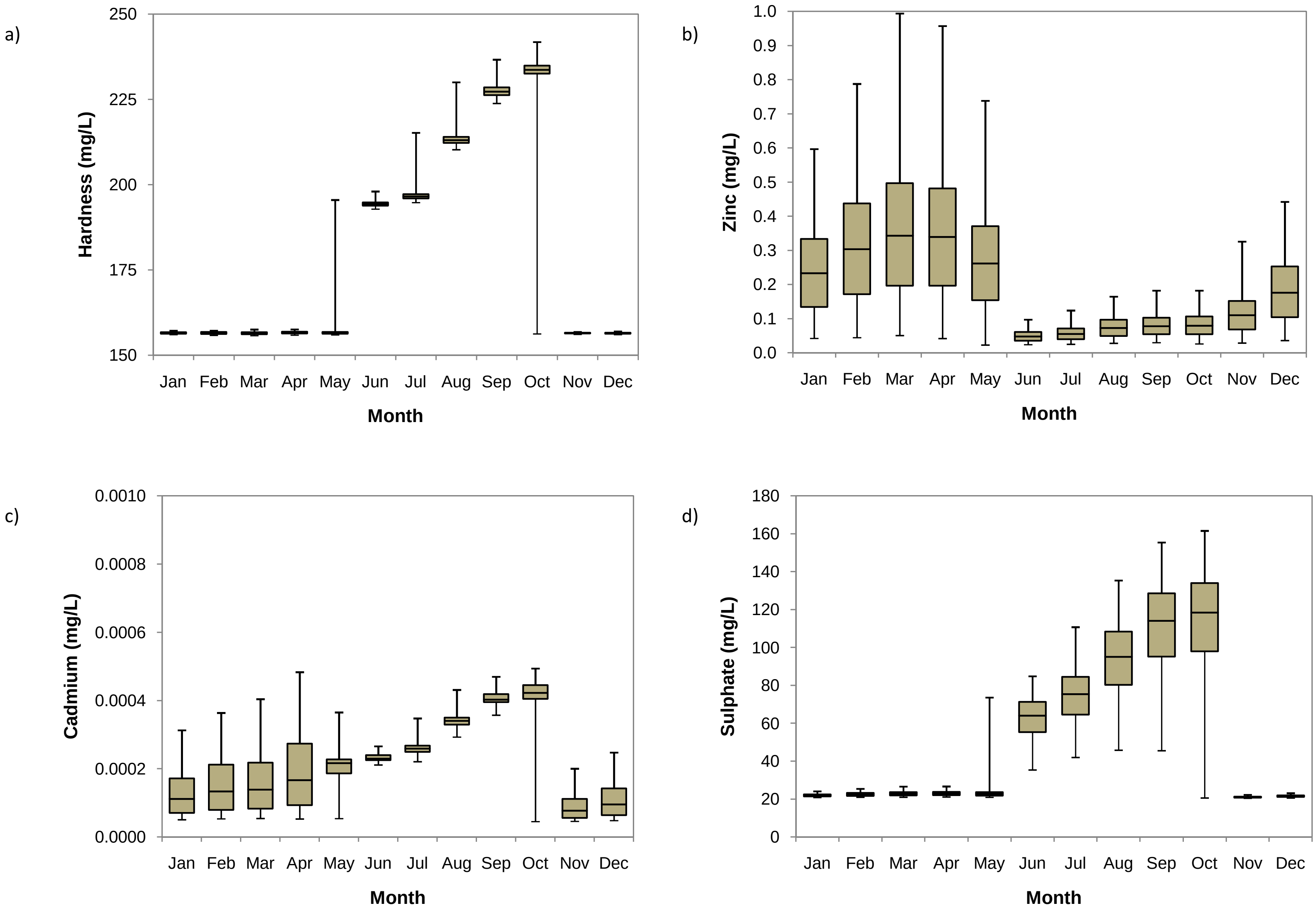

Figure 3.2: Predicted monthly zinc, cadmium, sulphate and hardness concentrations at X14, 2027-2212. "Boxes" represent 25th and 75th percentiles with solid lines within boxes representing median values. "Whiskers" represent minimum and maximum values. Data for the immediate post-closure period (2027 - 2036) are presented in Appendix Figure A.2.

3.2 Zinc

3.2.1 Recent and Predicted Concentrations

Median zinc concentrations downstream of the Faro Mine complex have been in the range 0.013-0.033 mg/L, but concentrations have been occasionally elevated above 0.100 mg/L at X14 (Table 3.1; Figure 3.3). Zinc and hardness concentrations at X14 have both tended to be highest in winter and early spring months (January-April) in recent years (Appendix Table A.1). This is at least partially attributable to groundwater inputs to the North Fork of Rose Creek, which have caused concentrations to be elevated in samples collected at X2 (Figure 3.3). No strong seasonal pattern in zinc concentrations has been evident at V27, although data are somewhat limited (n=13 sample; Appendix Table A.1).

Increasing zinc concentrations have been associated with elevated hardness concentrations (Figure 3.4). However, different relationships (slopes) are indicated between these two variables at X2, where there is relatively high influence from groundwater sources, compared to X14 and V27. Also, the range of hardness concentrations has been much greater at X14 than at the other stations.

After mine closure, median and maximum zinc concentrations at both V27 and X14 will continue to be highest during winter and early spring months (January-May) and lowest during June-July (Figures 3.1 and 3.2).

Median, post-closure concentrations of zinc at X2 (GEEC 2010) are expected to be less than half those currently observed based on planned remedial action along the North Fork Rose Creek (groundwater capture and elevation and lining of the creek channel). Therefore, any effects of zinc in the North Fork of Rose Creek will be temporary. However, median zinc concentrations at V27 and X14 are expected to rise 3- to 4-fold relative to current conditions (Tables 3.1 and 3.2). Consequently, concentrations further downstream are also expected to be well above current levels, with maxima potentially exceeding 0.1 mg/L down to the mouths of Vangorda and Anvil Creek, particularly over the longer term (Tables 3.1 and 3.2).

3.2.2 Effects on Biota

Zinc concentrations above 0.04 mg/L, which are predicted to occur throughout Vangorda and Rose Creeks (Table 3.2), have the potential to affect some sensitive algae and aquatic invertebrate species even at predicted water hardness >100 mg/L (Table 3.3; Figure 3.5). However, the majority of aquatic species would not likely be adversely

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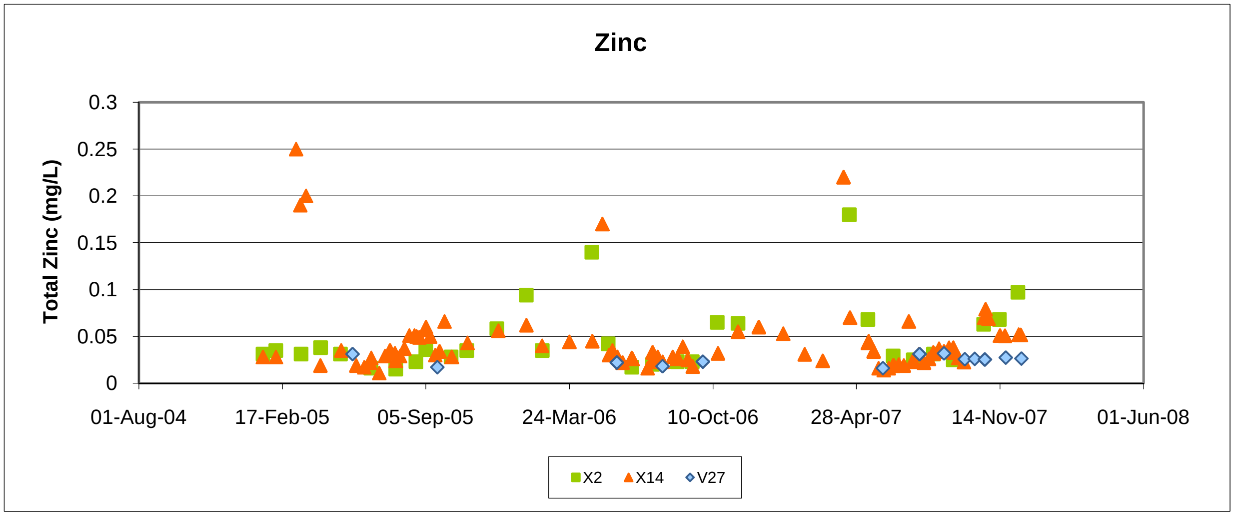

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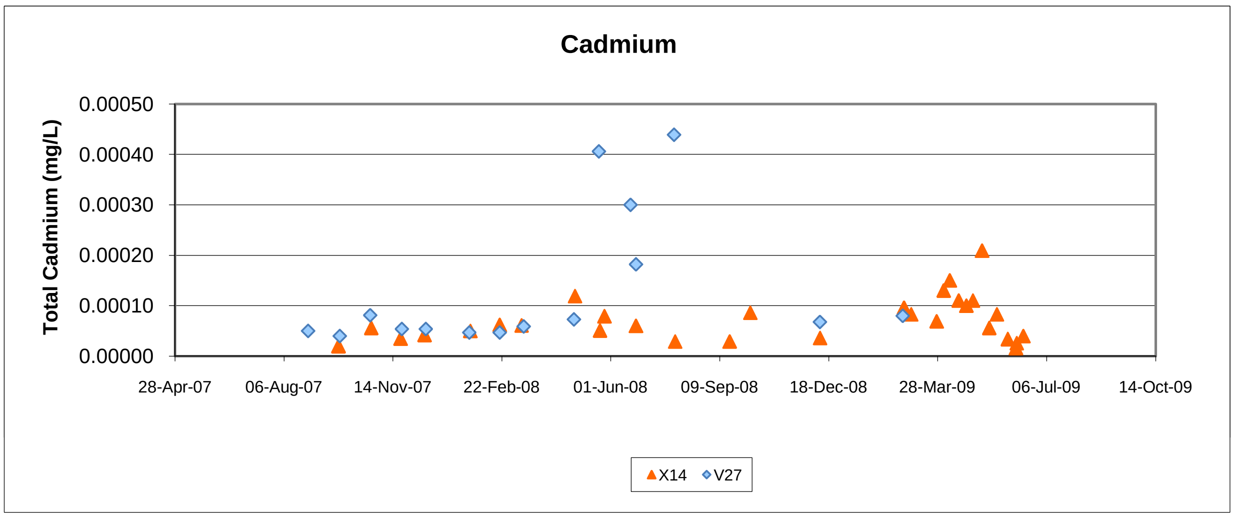

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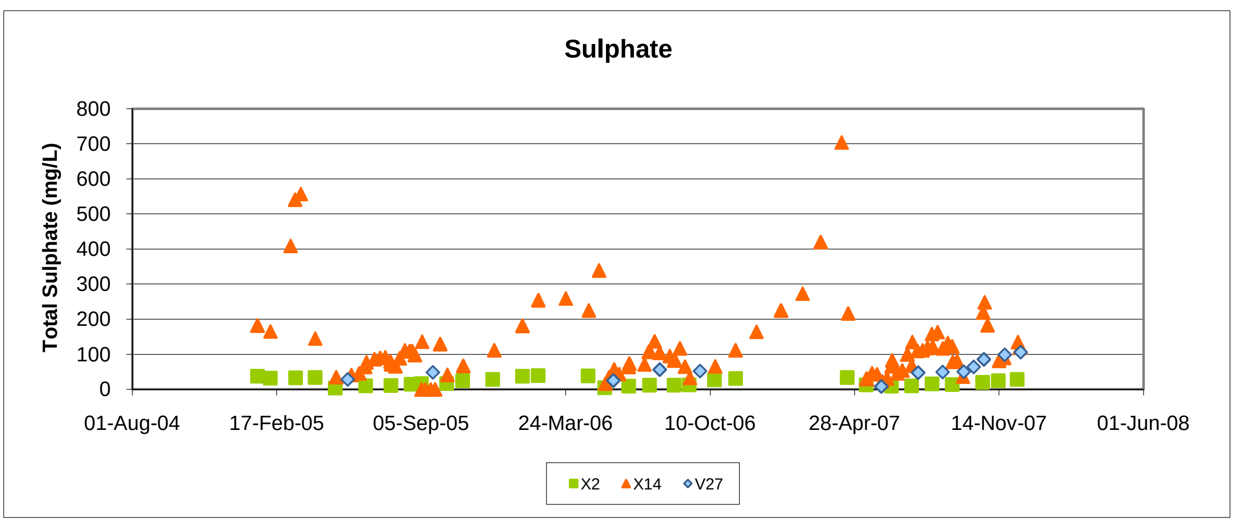
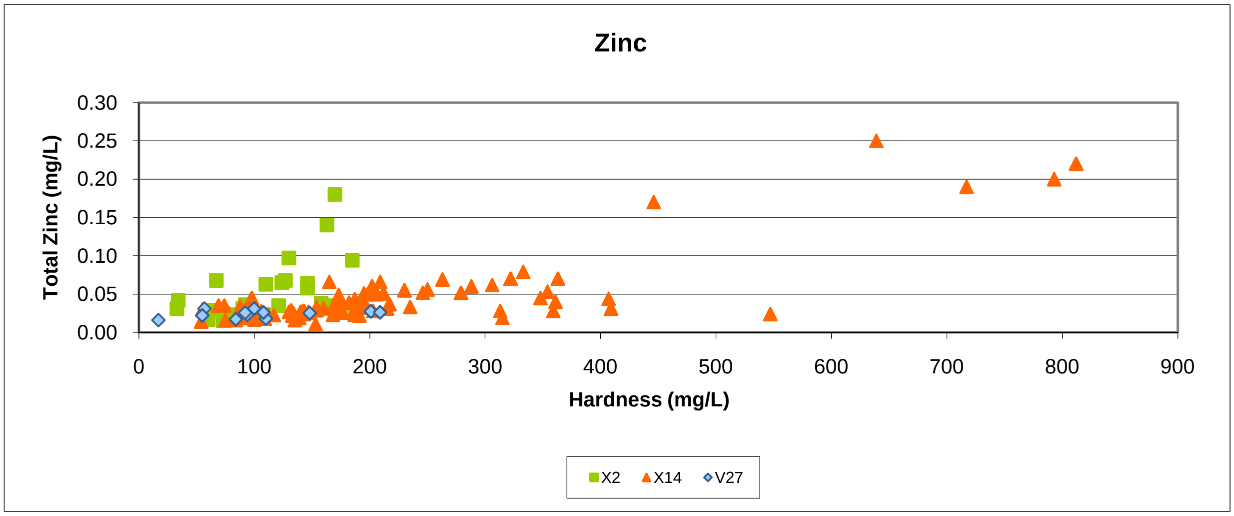


Figure 3.3: Concentrations of zinc, cadmium and sulphate at V27, X2 and X14 over time (2005 - 2007) except for cadmium for which 2008 - 2009 data were included to increase sample size having method detection limit above CWQG.

a)



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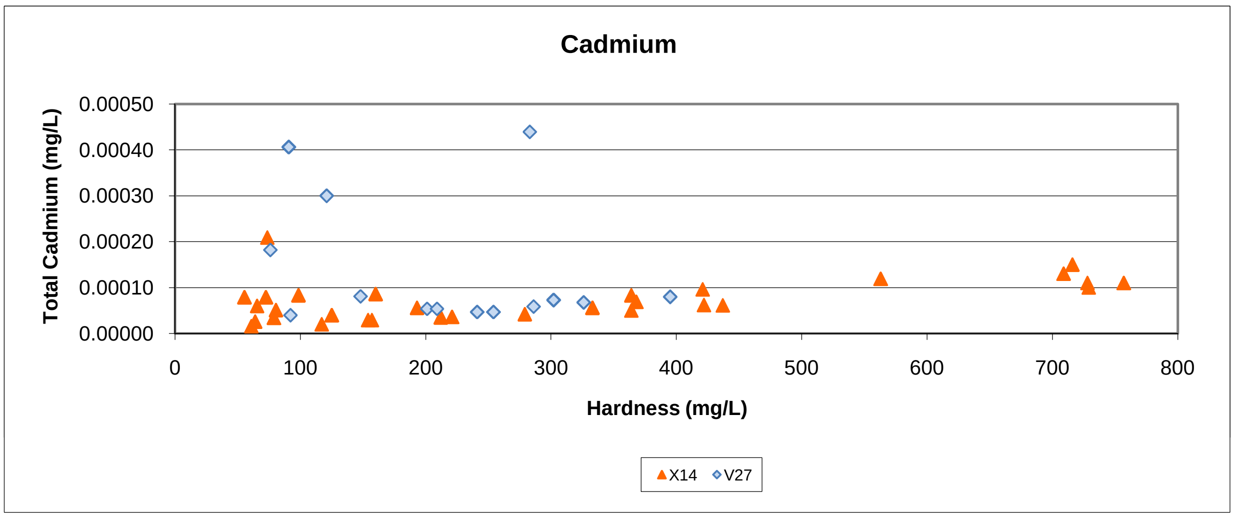

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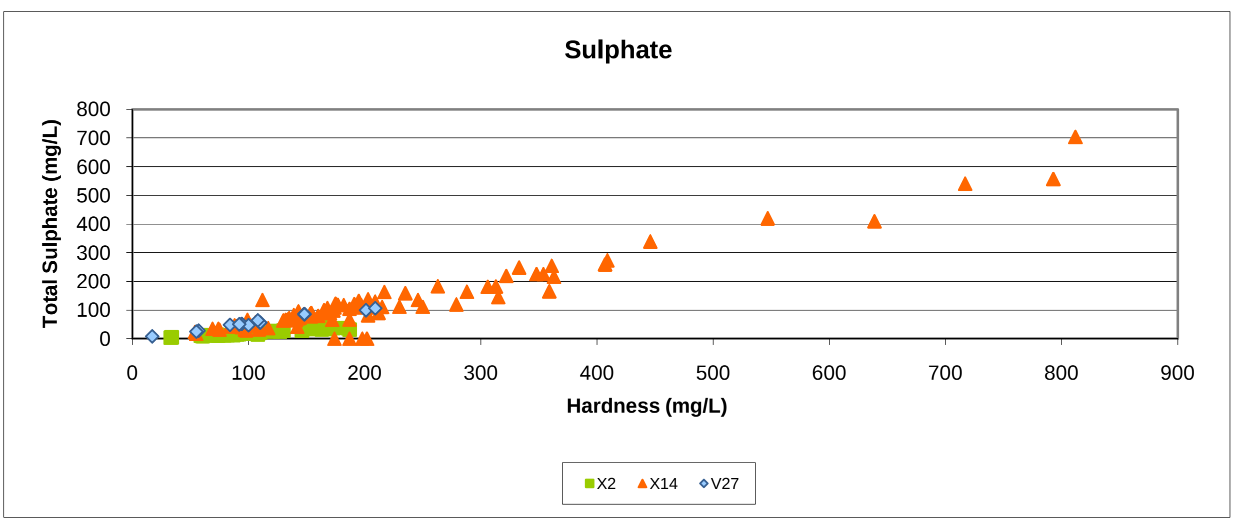


Figure 3.4: Relationship between water hardness and zinc, cadmium or sulphate concentrations in surface waters receiving drainage from Faro mine complex.

Table 3.3: Lowest effect endpoint reported for each freshwater species after a long-term exposure to zinc.

					Test Reported		Hardness-Adjusted Effect Concentration			
Species Common Name	Scientific Name	Duration	Endpoint	Observed Effect	Hardness (mg/L)	Effect Concentration (mg/L)	Effect Concentration (mg/L) at 50 mg/L Hardness [1]	Effect Concentration (mg/L) at 100 mg/L Hardness [1]	Effect Concentration (mg/L) at 200 mg/L Hardness [1]	Effect Concentration (mg/L) at 300 mg/L Hardness [1]
Green algae	*Pseudokirchneriella subcapitata*	7 d	EC10	Growth	NR	0.0011	0.0011	0.0011	0.0011	0.0011
Mayfly	*Epeorus latifolium*	4 weeks	IC10	emergence	83	0.0144	0.0094	0.0169	0.0303	0.0427
Water flea	*Ceriodaphnia dubia*	4 weeks	LOEC	Reproduction - Number of young per adult	97.6	0.025	0.014	0.026	0.046	0.065
Green alga	*Chlorella vulgaris*	72 h	EC50	biomass	NR	0.034	0.034	0.034	0.034	0.034
Water flea	*Daphnia magna*	50 d	MATC	Reproduction - Brood size	51.9	0.0217	0.0210	0.0378	0.0679	0.0957
Eurasian minnow	*Phoxinus phoxinus*	150 d	MATC	Growth	71	0.032	0.024	0.043	0.077	0.108
Zebra mussel	*Dreissena polymorpha*	10 weeks	EC50	Filtration rate	268	0.131	0.032	0.057	0.102	0.144
Snail	*Potamopyrgus jenkinsi*	12 weeks	MATC	Growth	159	0.091	0.034	0.061	0.110	0.156
Chironomids	*Tanytarsus dissimilis*	10 d	LC50	Mortality	46.8	0.0368	0.0389	0.0700	0.1257	0.1772
Rotifer	*Brachionus havanaensis*	18 d	EC10	Population growth inhibition	NR	0.0782	0.0782	0.0782	0.0782	0.0782
Green alga	*Chlorella pyrenoidosa*	24 h	MATC	Cell density	25.51	0.0283	0.0500	0.0898	0.1615	0.2275
Fathead minnow	*Pimephales promelas*	NR	EC10	Eggs adhesiveness	46	0.0469	0.0503	0.0905	0.1626	0.2292
Rainbow trout	*Oncorhynchus mykiss*	30 d	LC10	Mortality	31.72	0.0345	0.0507	0.0911	0.1638	0.2309
Green algae	*Scenedesmus quadricauda*	15 d	IC10	Growth	NR	0.0961	0.0961	0.0961	0.0961	0.0961
Chironomids	*Chironomus riparius*	11 weeks	LOEC	Development	NR	0.100	0.100	0.100	0.100	0.100
Mottled sculpin	*Cottus bairdi*	30 d	LC50	Mortality	48.6	0.032	0.033	0.059	0.106	0.149
Green hydra	*Hydra viridissima*	7 d	EC10	Population growth inhibition	20	0.0522	0.1134	0.2038	0.3664	0.5163
Chinook salmon	*Oncorhynchus tshawytscha*	200 h	LC10	Mortality	23	0.068	0.131	0.236	0.424	0.597
Amphipod	*Hyalella azteca*	7 d	LC50	Mortality	18	0.056	0.133	0.239	0.429	0.605
Duckweed	*Lemna minor*	7 d	IC10	Growth	NR	0.318	0.318	0.318	0.318	0.318
Brook Trout	*Salvelinus fontinalis*	24 w	MATC	egg fragility	45.9	0.174	0.187	0.336	0.604	0.852
Pink hydra	*Hydra vulgaris*	7 d	EC10	Population growth inhibition	20	0.1779	0.3863	0.6943	1.2481	1.7588
Common duckmeat	*Spirodela polyrrhiza*	4 d	IC50	Growth	NR	0.935	0.935	0.935	0.935	0.935
Cutthroat trout	*Oncorhynchus clarkii*	14 d	LC10	Mortality	40	0.453	0.547	0.983	1.768	2.491
Sea trout	*Salmo trutta*	14 d	LC10	Mortality	39	0.504	0.622	1.118	2.009	2.832
Bryozoan	*Pectinatella magnifica*	96 h	LC10	Mortality	205	2.286	0.693	1.245	2.239	3.155
Star duckweed	*Lemna trisulca*	14 d	EC50	final yield (oven dry weight)	20.37	0.327	0.699	1.256	2.258	3.183
Atlantic salmon	*Salmo salar*	14 d	LC50	Mortality	351	3.640	0.700	1.258	2.262	3.187
Snail	*Physa gyrina*	30 d	LC50	Mortality	36	0.771	1.018	1.830	3.289	4.635
Bryozoan	*Plumatella emarginata*	96 h	LC10	Mortality	205	3.474	1.053	1.893	3.402	4.794
Bryozoan	*Lophopodella carteri*	96 h	LC50	Mortality	205	4.093	1.241	2.230	4.008	5.649
Diatom	*Cyclotella meneghiniana*	5 d	LC10	Growth rate	121	2.803	1.327	2.386	4.288	6.043
Bluegill	*Lepomis macrochirus*	20 d	TLM	Mortality	370	11.300	2.078	3.736	6.715	9.463
Mayfly	*Rhithrogena hageni*	10 d	EC10	Mortality	44.4	2.069	2.288	4.113	7.392	10.417
Green alga	*Chlamydomonas sp.*	10 d	LC10	Growth rate	121	8.381	3.968	7.133	12.821	18.068
Crayfish	*Orconectes virilis*	14 d	LC10	Mortality	26	9.920	17.249	31.006	55.733	78.540

[1] If adjusted from another hardness, value was calculated using the following equation: EXP(LN(EFFECT conc)-(0.846)*(LN(measured water hardness)-LN(desired water hardness)))

NR - not reported

(Shaded) Species not relevant at Faro

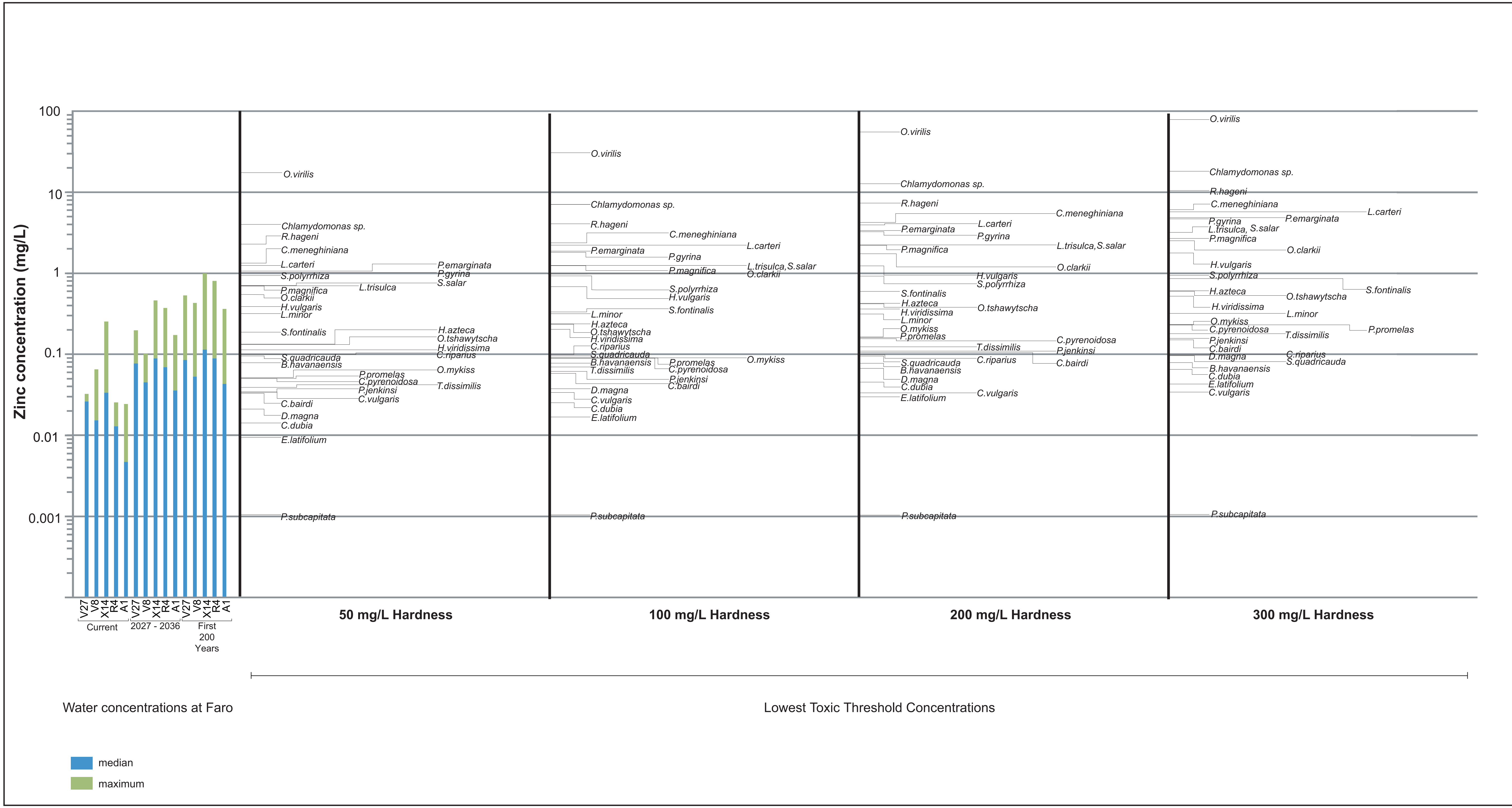


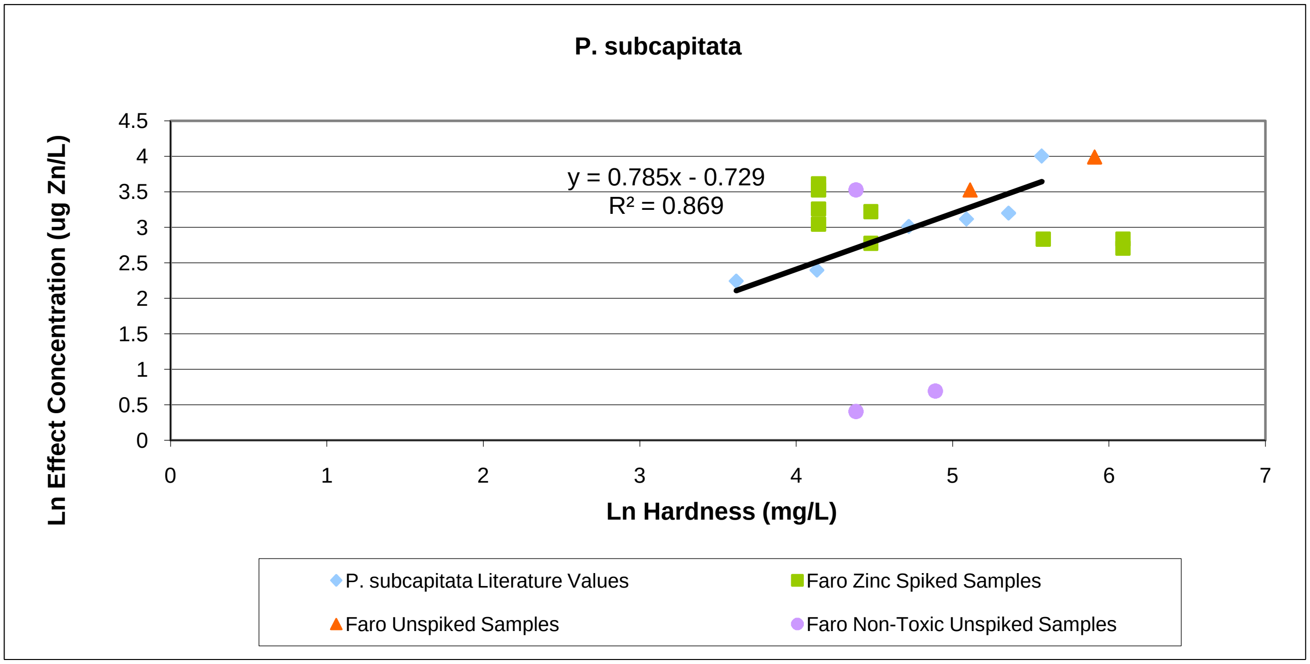
Figure 3.5: Current and predicted concentrations of zinc relative to the lowest toxicity thresholds reported in the literature for various aquatic species based on long-term exposures and various water hardness values.

affected at predicted median zinc (≤0.088 mg/L) and hardness (>150 mg/L) levels, including Chinook salmon, which is a valued local resource.

However, at predicted *maximum* zinc concentrations (0.1-1.0 mg/L; Table 3.2) additional species could be impacted, including Chinook salmon, depending on coincident hardness concentrations and the period over which such concentrations are sustained (e.g., if sustained for days or weeks). In winter, when zinc concentrations are expected to be highest, water hardness will be lowest (median concentrations <170 mg/L) (Figures 3.1 and 3.2), suggesting this will be the period of greatest vulnerability to resident biota. As a late summer spawner (Scott and Crossman 1998), developing eggs and possibly early post-hatch stages of Chinook salmon will be exposed to winter maximum zinc concentrations in the vicinity of and downstream of the Faro Mine. Data in the scientific literature indicate these early developmental stages are particularly sensitive to zinc relative to older juvenile or adult stages (Benoit and Holcombe 1978, Chapman 1978, Buhl and Hamilton 1991, Williams and Holdway 2000, Huang et al. 2009). By comparison, arctic grayling and slimy sculpin spawn in spring when daytime water temperatures reach 7°C or more (Scott and Crossman 1998; Minnow and WMEC 2009), so the life stages of these species most likely to be exposed to maximum zinc concentrations downstream of the Faro Mine will be six months of age or older.

Toxicity tests were previously conducted on surface water samples collected in the vicinity of Faro Mine (Vizon Scitec 2004). Some tests were conducted directly on the samples received by the laboratory to test potential toxicity associated with substances contained in the samples (e.g., zinc and possibly others), while other tests involved addition of zinc to the samples, specifically to characterize zinc toxicity in site water. Samples collected from locations downstream of mine influences (V8, X2, X10, X14) may have contained other mine-related contaminants than zinc but analytical data accompanying the toxicity test data were limited (e.g., zinc and hardness values only). Observed toxicity to the alga *P. subcapitata* for the samples tested could be accounted for solely on the basis of zinc concentrations based on good agreement with the zinc concentrations shown to cause toxicity to the same species at similar water hardness in other studies presented in the scientific literature (Figure 3.6). Several tests using *Ceriodaphnia dubia* exposed to Faro Mine water samples were also generally consistent with expected zinc toxicity based on other studies in the literature, except for two tests which were toxic at lower zinc concentrations, which likely reflected the presence of one or more additional toxicants (Figure 3.6). There were no definitive hardness-toxicity relationships indicated by the toxicity tests conducted using either species in site water, suggesting that toxicity may

a)



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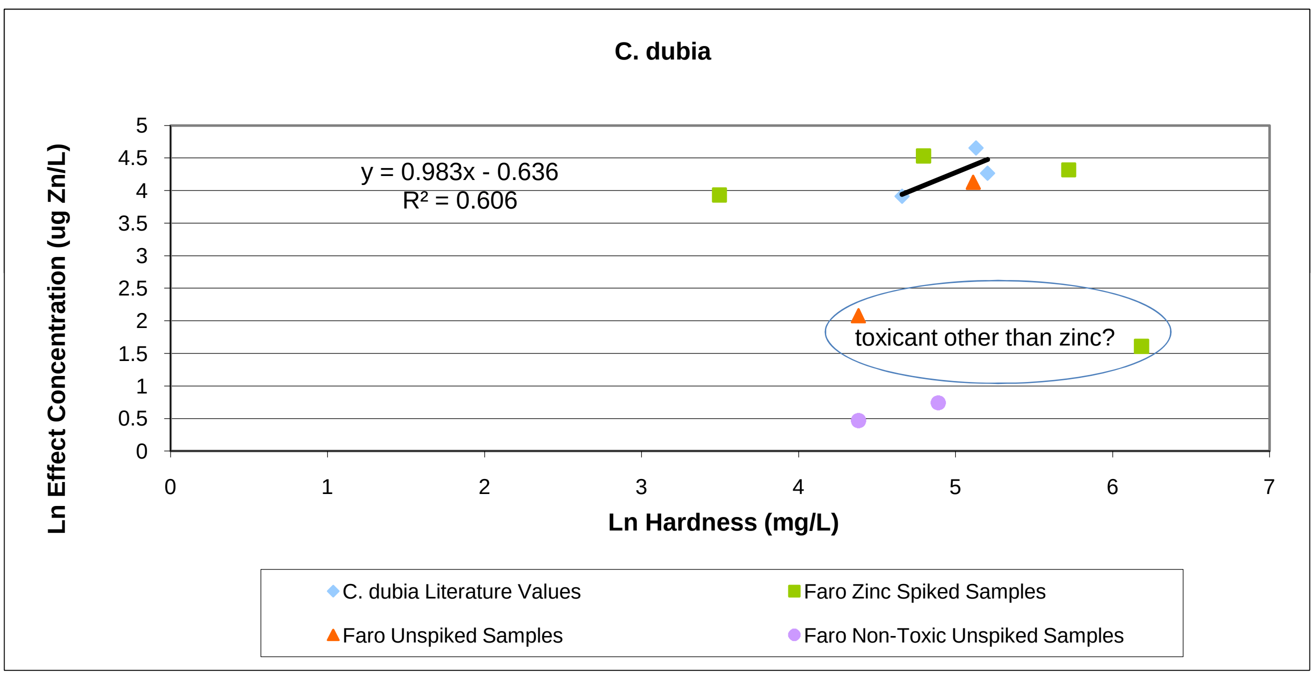

Figure 3.6: Toxicity of zinc to *P. subcapitata* and *Ceriodaphnia dubia* in surface water samples collected at Faro Mine (detailed test data presented in Appendix Table B.1).

have also been influenced by other water quality factors (e.g., pH) or contaminants. Effects to *P. subcapitata* and *C. dubia* were indicated at concentrations of approximately 0.03 and 0.04 mg/L, respectively, which are in the range of values reported for these species in the literature (Appendix Tables B.1 and B.2). This provides further evidence that some aquatic biota may be affected by zinc in the range of concentrations predicted to occur in Rose Creek after mine closure, particularly if predicted maxima are realized over sustained periods.

Zinc-related effects are highly unlikely to extend into the Pelly River where mine-related concentrations will be diluted well below those associated with effects on aquatic biota (Table 3.3). Median and maximum zinc concentrations in the Pelly River downstream of Vangorda Creek (P2) and Anvil Creek (P4) are predicted to be approximately 0.02 mg/L (Table 3.2), which is equivalent to mean concentrations measured in the Pelly River upstream of Faro Mine inputs (P1; Minnow 2009).

3.3 Cadmium

3.3.1 Recent and Predicted Concentrations

Cadmium concentrations immediately downstream of the Faro Mine have generally been around 0.00006 mg/L (V27 and X14), but have occasionally risen to 0.0003 mg/L or more (Table 3.1). After closure, median cadmium concentrations at X14 are expected to rise slightly, with maximum concentrations of up to approximately 0.0005 mg/L (Table 3.2). Limited available data for recent years do not suggest a strong relationship between cadmium and water hardness concentrations (Figure 3.4), but both variables are expected to reach maximum levels in late summer months (September- October) after mine closure (Figures 3.1 and 3.2).

Cadmium inputs from the Faro Mine are not expected to affect water quality in the Pelly River. Median and maximum cadmium concentrations in the Pelly River downstream of Vangorda Creek (P2) and Anvil Creek (P4) are predicted to be approximately 0.0002 mg/L (Table 3.2), which is equivalent to mean concentrations measured in the Pelly River upstream of Faro Mine inputs (P1; Minnow 2009).

3.3.2 Effects on Biota

Most aquatic biota exhibit cadmium toxicity at concentrations above 0.0005 mg/L at water hardness of 100 mg/L or more (Table 3.4), and thus would not likely be affected at the concentrations occurring and expected downstream of the Faro Mine (≤0.0005 mg/L). However, a few species have shown toxicity at low concentrations, such as water fleas

Table 3.4: Lowest effect endpoint reported for each freshwater species after a long-term exposure to cadmium.

Species Common Name	Scientific Name	Duration	Endpoint	Observed Effect	Test Hardness (mg/L)	Reported Effect Concentration (mg/L)	Hardness-Adjusted Effect Concentration			
							Effect Concentration (mg/L) at 50 mg/L Hardness [1]	Effect Concentration (mg/L) at 100 mg/L Hardness [1]	Effect Concentration (mg/L) at 200 mg/L Hardness [1]	Effect Concentration (mg/L) at 300 mg/L Hardness [1]
Water flea	*Daphnia magna*	7 d	EC10	Reproduction - Brood size	179	0.00014	0.00004	0.00008	0.00016	0.00024
Water flea	*Ceriodaphnia reticulata*	7 d	MATC	Reproduction - Number of young per adult	240	0.00043	0.00009	0.00018	0.00036	0.00054
Amphipod - scud	*Hyalella azteca*	28 d	IC25	Biomass, decrease in	280	0.00051	0.00009	0.00018	0.00036	0.00055
Rainbow trout	*Oncorhynchus mykiss*	65 wks	MATC	Reproduction - delay in oogenesis	250	0.00091	0.00018	0.00036	0.00072	0.00110
Midge	*Chironomus tentans*	60 d	IC25	Hatching success	280	0.004	0.001	0.001	0.003	0.004
Mottled sculpin	*Cottus bairdi*	21 d	EC50	Biomass, decrease in	104	0.00177	0.00084	0.00170	0.00346	0.00523
Atlantic salmon	*Salmo salar*	496 d	LOEC/L	Weight and Length	28	0.00047	0.00085	0.00173	0.00351	0.00532
Bull trout	*Salvelinus confluentus*	55 d	MATC	Growth	30.6	0.00055	0.00091	0.00184	0.00375	0.00567
Green hydra	*Hydra viridissima*	7 d	NOEC/L	Population growth inhibition	19.5	0.0004	0.0010	0.0021	0.0043	0.0066
Amphipod - gammarid	*Echinogammarus meridionalis*	6 d	LOEC/L	Feeding inhibition	263.4	0.0064	0.0012	0.0024	0.0048	0.0073
European shrimp	*Atyaephyra desmarestii*	6 d	LOEC/L	Feeding inhibition	263.4	0.0065	0.0012	0.0024	0.0049	0.0075
Amphipod - gammarid	*Gammarus pulex*	5 d	LOEC/L	Mortality	269.2	0.0075	0.0013	0.0027	0.0055	0.0084
Brown trout	*Salmo trutta*	30 d	IC20	Biomass, decrease in	29.2	0.0009	0.0015	0.0031	0.0062	0.0094
Brook Trout	*Salvelinus fontinalis*	126 d	MATC	Biomass, decrease in	45	0.002	0.002	0.005	0.009	0.014
Coho salmon	*Oncorhynchus kisutch*	27 d	MATC	Biomass, decrease in	45	0.0021	0.0023	0.0048	0.0097	0.0146
Chinook salmon	*Oncorhynchus tshawytscha*	8 d	LC10	Mortality	23	0.0012	0.0027	0.0054	0.0110	0.0166
Water flea	*Daphnia pulex*	14 d	MATC	Reproduction - Number of young per adult	240	0.0137	0.0028	0.0056	0.0114	0.0172
Green algae	*Ankistrodesmus falcatus*	96 h	NOEC/L	Growth	118.0	0.01	0.00	0.01	0.02	0.03
Fathead minnow	*Pimephales promelas*	10 d	MATC	Mortality	17.0	0.0014	0.0042	0.0086	0.0174	0.0264
Water flea	*Ceriodaphnia dubia*	14 d	MATC	Reproduction	17.0	0.002	0.006	0.012	0.025	0.038
White Sucker	*Catostomus commersoni*	40 h	MATC	Biomass, decrease in	45	0.0071	0.0079	0.0161	0.0327	0.0494
Northern pike	*Esox lucius*	35 d	MATC	Biomass, decrease in	45	0.0074	0.0082	0.0167	0.0340	0.0515
Lake Trout	*Salvelinus namaycush*	41 d	MATC	Biomass, decrease in	45	0.0074	0.0082	0.0167	0.0340	0.0515
Marsh snail	*Lymnaea palustris*	4 weeks	EC50	Growth	284	0.0582	0.0098	0.0200	0.0407	0.0616
Great pond snail	*Lymnaea stagnalis*	4 weeks	NOEC/L	Growth	284	0.08	0.01	0.03	0.06	0.08
Midge	*Chironomus riparius*	17 d	MATC	Mortality	98.0	0.0474	0.0238	0.0484	0.0983	0.1489
Duckweed	*Lemna minor*	7 d	EC50	Growth rate	166.0	0.214	0.063	0.127	0.259	0.392
Northwestern salamander	*Ambystoma gracile*	24 d	MATC	Weight	45	0.0972	0.1083	0.2200	0.4471	0.6769

[a] Long-term exposure results were adjusted to a common hardness based on a combined slope of 1.023

(shaded) Species not relevant at Faro

(*Daphnia magna* and *Ceriodaphnia reticulata*), as well as the amphipod *Hyallela azteca* (Table 3.4, Figure 3.7). These species prefer lentic (slow flowing) environments more than the flowing, riverine habitat downstream of the Faro Mine. Nevertheless, potential presence at Faro of similarly sensitive lotic invertebrate species cannot be ruled out. Although rainbow trout have also shown relatively high toxicity to cadmium, salmonid species more relevant to the Faro site (e.g., Chinook salmon) appear to be less sensitive (e.g. toxicity at concentrations ≥ 0.005 mg/L at hardness of at least 100 mg/L). Furthermore, elevated cadmium concentrations are expected to occur in months when hardness levels will also be elevated (Figures 3.1 and 3.2), so the potential for effects will be less than if cadmium was high when hardness was low. Future cadmium concentrations in lower Anvil Creek will usually be below levels associated with effects on aquatic biota. Overall, it is expected that any future effects related to cadmium levels downstream of the Faro Mine will be very limited. In the Pelly River, mine-related cadmium loads are not expected to increase water concentrations above background levels (Section 3.3.1), and thus will not affect biota there.

3.4 Sulphate

3.4.1 Recent and Predicted Concentrations

Sulphate concentrations downstream of the Faro Mine are typically 120 mg/L or less, but have ranged as high as 704 mg/L at X14, downstream of the tailings area (Table 3.1). Following mine closure, sulphate levels are expected to be similar to or slightly lower than current concentrations (Table 3.2). Elevated sulphate concentrations generally coincide with elevated water hardness (Figure 3.4), and both variables are expected to reach maximum levels during summer months following mine closure (Figures 3.1, 3.2)

3.4.2 Effects on Biota

Of species tested to date, those most sensitive to sulphate have been striped bass, the amphipod *Hyallela azteca*, and the aquatic moss *Fontinalis anitpyretica*, all of which have shown sulphate effects at concentrations between 250 and 275 mg/L (at hardness of 100 mg/L; Table 3.5; Figure 3.8). Striped bass is a temperate species found only in coastal areas of the U.S. and eastern Canada (Scott and Crossman 1998) and thus not relevant at Faro. *Hyallela* and *Fontilalis* are both well distributed in Western Canada (Warrington 1994, Witt and Hebert 2000). Sulphate effects on all other species tested to date have occurred at concentrations greater than 700 mg/L (at hardness of 100 mg/L or more; Table 3.5).

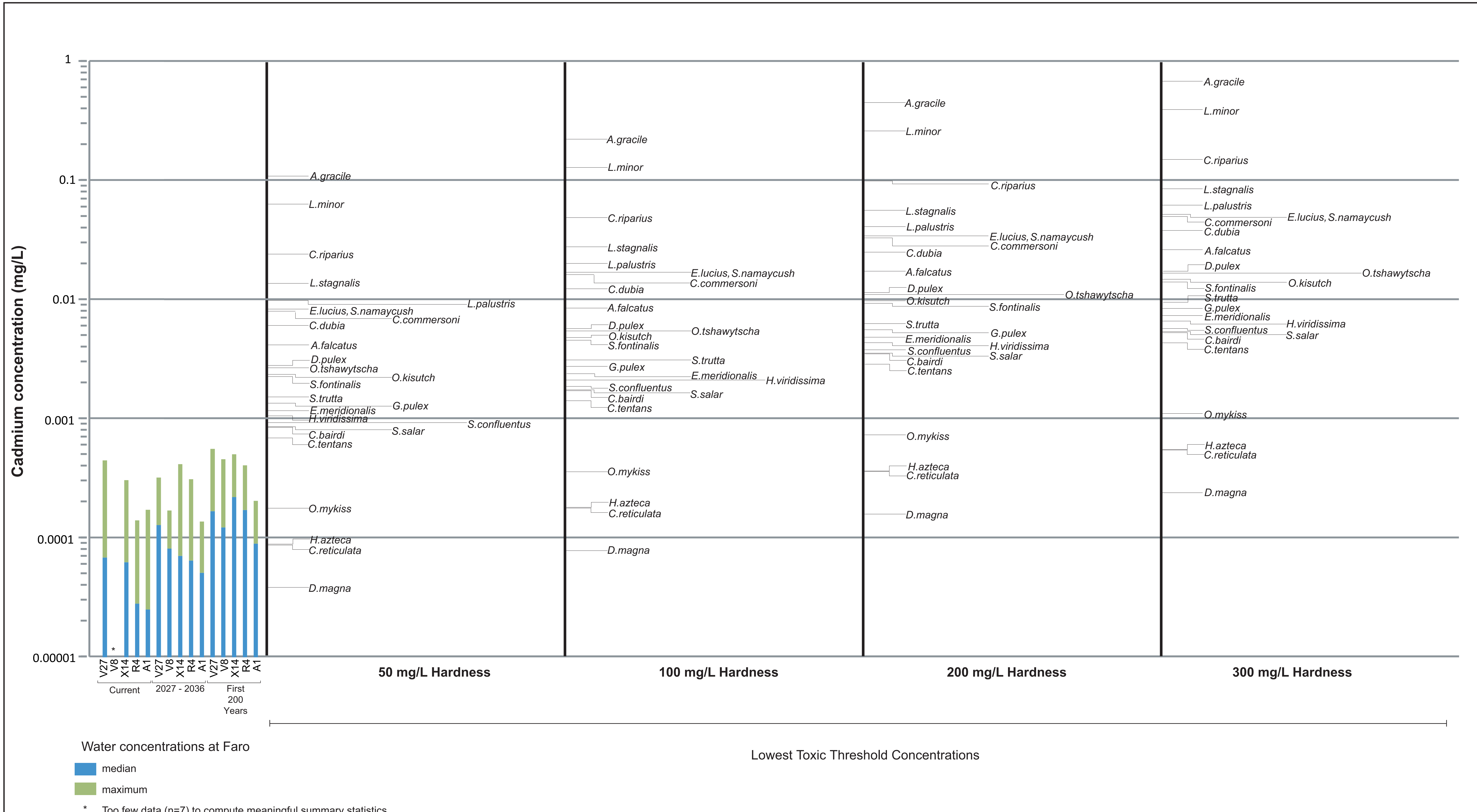

Figure 3.7: Current and predicted concentrations of cadmium relative to the lowest toxicity thresholds reported in the literature for various aquatic species based on long-term exposures and various water hardness values.

Table 3.5: Relative sensitivity of aquatic species to sulphate (long-term exposure data, if available, otherwise short-term data are presented).

Common Name	Scientific Name	Long Term/ Short Term Exposure	Actual Test Duration (days)	Endpoint	Effect	Test Hardness (mg/L)	Reported Effect Concentration (mg/L)	Hardness-Adjusted Effect Concentration			
								Sulphate Effect Concentration at 50 mg/L hardness [1]	Sulphate Effect Concentration at 100 mg/L hardness [1]	Sulphate Effect Concentration at 200 mg/L hardness [1]	Sulphate Effect Concentration at 300 mg/L hardness [1]
striped bass larvae	*Morone saxatilis*	short	4 days	LC50	mortality	-	250	250	250	250	250
aquatic moss	*Fontinalis antipyretica*	long	21 days	MATC	shoot dry wt	105	283	158	272	470	647
amphipod	*Hyalella azteca*	short	4 days	LC10	mortality	94	262	159	275	475	654
fathead minnow	*Pimephales promelas*	long	7 days	MATC	survival	100	735	426	735	1269	1747
water flea	*Daphnia magna*	long	21 days	IC25	reproduction	100	833	482	833	1438	1980
green alga	*Chlorella vulgaris*	long	91.3 days	MATC	population growth	-	876	876	876	876	876
water flea	*Ceriodaphnia*	long	7 days	IC25	reproduction	100	1267	734	1267	2188	3011
rainbow trout	*Oncorhyncus mykiss*	long	7 days	EC25	viability	100	1280	741	1280	2210	3042
diatom	*Nitzschia linearis*	long	5 days	LC50	mortality	-	1285	1285	1285	1285	1285
fingernail clam	*Sphaerium simile*	short	4 days	LC10	mortality	94	1502	913	1577	2723	3748
green alga	*Pseudokerchneriella subcapitata*	long	3 days	MATC	growth	100	1967	1139	1967	3396	4675
bluegill	*Lepomis macrochirus*	short	1 day	LC50	mortality	-	2102	2102	2102	2102	2102
pond snail	*Lymnaea sp*	short	4 days	EC50	hatching	-	2402	2402	2402	2402	2402
Eurasian milfoil	*Myriophyllum spicatum*	long	32 days	EC50	growth	-	2785	2785	2785	2785	2785
minnow, carp	*Cyprinidae*	short	1 day	mortality	mortality	-	3042	3042	3042	3042	3042
chironomid	not given	short	4 days	LC50	mortality	100	5868	5868	5868	10132	13946
mosquito	*Culex sp*	short	1 day	LC50	mortality	-	7727	7727	7727	7727	7727
coho salmon	*Oncorhynchus kisutch*	short	4 days	LC50	mortality	100	9550	9550	9550	16490	22697
Sailfin molly	*Poecillia latipinna*	short	2 days	LC50	mortality	-	10814	10814	10814	10814	10814

[1] If adjusted from another hardness, value was calculated using the following equation: EXP(LN(EFFECT conc)-(0.788)*(LN(measured water hardness)-LN(desired water hardness)))
If original test hardness was not reported, the same toxicity value is shown for all hardnesses.
(grey shading) Species not relevant at Faro

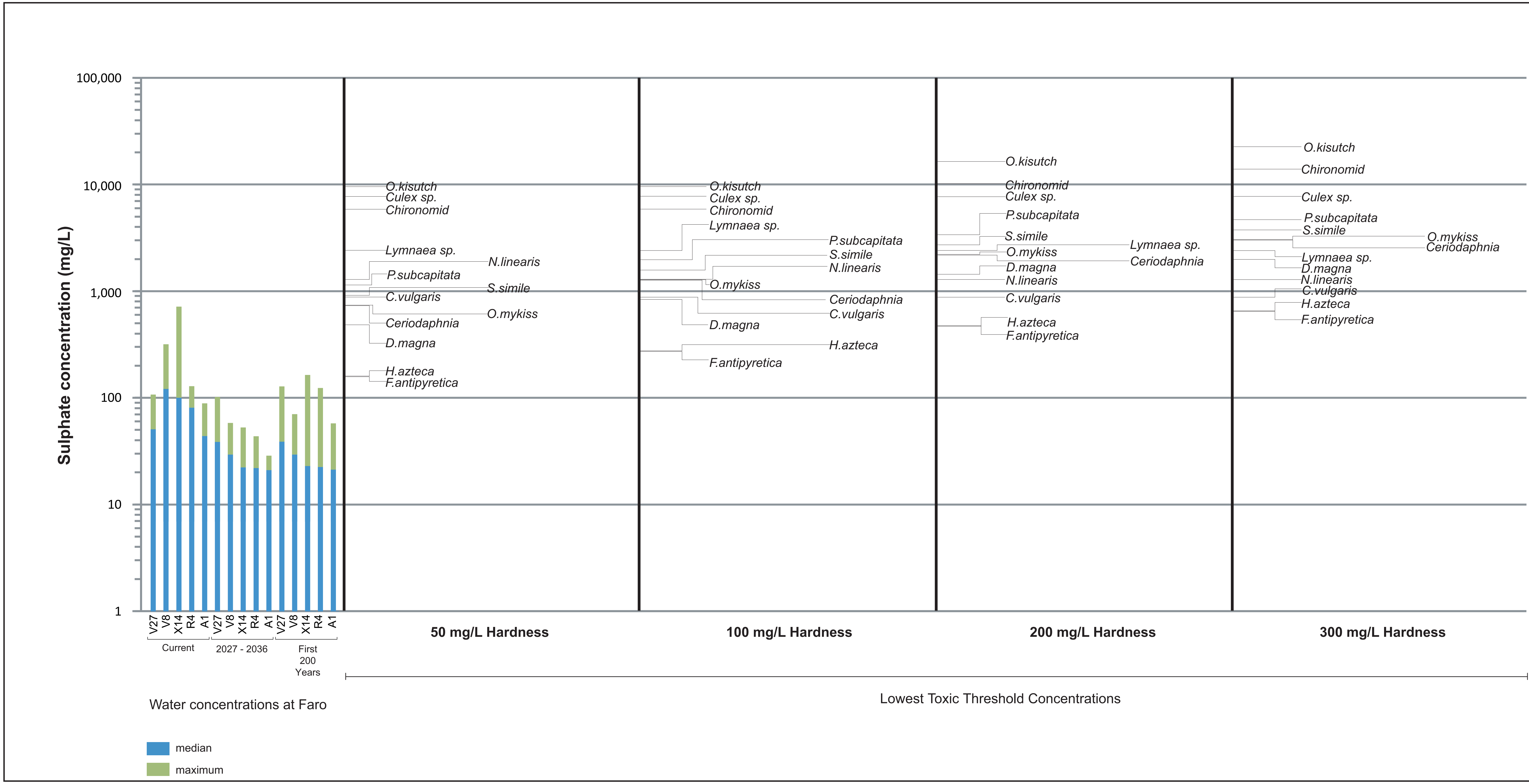

Figure 3.8: Current and predicted concentrations of sulphate relative to the lowest toxicity threshold reported in the literature for various aquatic species and water hardness values.

As sulphate concentrations are expected to be lower than current levels, no effects to aquatic biota would be expected from exposure to sulphate downstream of the Faro Mine.

4.0 CONCLUSIONS

Effects on aquatic biota associated with current levels of zinc, cadmium and sulphate downstream of the Faro Mine appear to be absent or very limited. Concentrations of sulphate predicted for the first 185 years post-closure are also not expected to adversely affect biota. Potential cadmium effects on biota, if any, will be limited to the most highly sensitive algal and invertebrate species in near-field areas, but not fish. Predicted zinc concentrations have the potential to adversely impact fish and other biota within the Rose-Anvil and Vangorda drainages, particularly if predicted maxima are realized over sustained periods. This may occur during winter months when highest concentrations of zinc and lowest water hardness are expected, coinciding with embryo-larval development of Chinook salmon. However, zinc concentrations in the Pelly River downstream of the Faro Mine inputs are expected to remain comparable to upstream background concentrations.

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APPENDIX A

Water Quality Data

Table A.1: Hardness, sulphate and zinc data collected at Faro Stations, 2005 - 2007

Station	Name	Date	Hardness (mg/L)	Sulphate (mg/L)	Zinc - total (mg/L)
V8	Vagorda Ck in Faro	21-Jan-05	373	159	0.012
V8	Vagorda Ck in Faro	08-Feb-05	374	155	0.014
V8	Vagorda Ck in Faro	15-Mar-05	395	176	0.009
V8	Vagorda Ck in Faro	11-Apr-05	382	175	0.011
V8	Vagorda Ck in Faro	09-May-05	116	33.3	0.037
V8	Vagorda Ck in Faro	20-Jun-05	214	133	0.022
V8	Vagorda Ck in Faro	25-Jul-05	321	238	0.024
V8	Vagorda Ck in Faro	22-Aug-05	449	312	0.015
V8	Vagorda Ck in Faro	05-Sep-05	210	102	0.026
V8	Vagorda Ck in Faro	10-Oct-05	237	82.1	0.007
V8	Vagorda Ck in Faro	01-Nov-05	275	112	0.031
V8	Vagorda Ck in Faro	14-Dec-05	328	139	0.022
V8	Vagorda Ck in Faro	24-Jan-06	384	166	0.015
V8	Vagorda Ck in Faro	13-Feb-06	381	191	0.017
V8	Vagorda Ck in Faro	24-Mar-06	402	204	0.019
V8	Vagorda Ck in Faro	24-Apr-06	356	184	0.013
V8	Vagorda Ck in Faro	17-May-06	143	51.9	0.022
V8	Vagorda Ck in Faro	19-Jun-06	118	35	0.011
V8	Vagorda Ck in Faro	17-Jul-06	143		0.01
V8	Vagorda Ck in Faro	21-Aug-06	309	85	0.028
V8	Vagorda Ck in Faro	21-Aug-06	174	61.5	0.01
V8	Vagorda Ck in Faro	11-Sep-06	166	58.7	0.01
V8	Vagorda Ck in Faro	16-Oct-06	230	84	0.011
V8	Vagorda Ck in Faro	14-Nov-06	312	130	0.013
V8	Vagorda Ck in Faro	13-Dec-06	328	144	0.028
V8	Vagorda Ck in Faro	15-Jan-07	362	165	0.064
V8	Vagorda Ck in Faro	13-Feb-07	369	163	0.011
V8	Vagorda Ck in Faro	11-Mar-07	410	201	0.028
V8	Vagorda Ck in Faro	18-Apr-07	371	185	0.045
V8	Vagorda Ck in Faro	14-May-07	197	61.2	0.018
V8	Vagorda Ck in Faro	18-Jun-07	112	35.8	0.03
V8	Vagorda Ck in Faro	16-Jul-07	133	48.4	0.017
V8	Vagorda Ck in Faro	13-Aug-07	202	73	0.019
V8	Vagorda Ck in Faro	27-Aug-07		65.9	0.0091
V8	Vagorda Ck in Faro	27-Aug-07		66.5	0.009
V8	Vagorda Ck in Faro	10-Sep-07	180	74	0.007
V8	Vagorda Ck in Faro	23-Oct-07	260	99.8	0.01
V8	Vagorda Ck in Faro	13-Nov-07	282	111	0.01
V8	Vagorda Ck in Faro	09-Dec-07	293	129	0.013
n			37	38	39
minimum			112.0	33.3	0.007
maximum			449	312	0.064
median			293	120.5	0.015
mean			278	123	0.019
standard deviation			100	63.8	0.012
standard error			16.5	10.35	0.002
# < detection limit			0	0	0
% <detection limit			0	0	0
# >criterion			-	34	4
% >criterion			-	89	10
99th percentile			435	284.62	0.057
95th percentile			404	209	0.038
90th percentile			388	194	0.030
water quality criterion			-	50	0.03

Table A.1: Hardness, sulphate and zinc data collected at Faro Stations, 2005 - 2007

Station	Name	Date	Hardness (mg/L)	Sulphate (mg/L)	Zinc - total (mg/L)
X2	X2, N Fork Rose Cr	21-Jan-05	173	37.2	0.031
X2	X2, N Fork Rose Cr	08-Feb-05	187	31.8	0.035
X2	X2, N Fork Rose Cr	15-Mar-05	163	33.2	0.031
X2	X2, N Fork Rose Cr	11-Apr-05	158	34	0.038
X2	X2, N Fork Rose Cr	09-May-05	33	4	0.031
X2	X2, N Fork Rose Cr	20-Jun-05	74	10.5	0.016
X2	X2, N Fork Rose Cr	25-Jul-05	73	10.6	0.015
X2	X2, N Fork Rose Cr	22-Aug-05	108	15.1	0.023
X2	X2, N Fork Rose Cr	05-Sep-05	92	16.4	0.036
X2	X2, N Fork Rose Cr	10-Oct-05	96	16.6	0.028
X2	X2, N Fork Rose Cr	01-Nov-05	121	24.6	0.035
X2	X2, N Fork Rose Cr	13-Dec-05	146	28.1	0.058
X2	X2, N Fork Rose Cr	23-Jan-06	185	37.2	0.094
X2	X2, N Fork Rose Cr	14-Feb-06	163	39.7	0.035
X2	X2, N Fork Rose Cr	24-Apr-06	163	38.8	0.14
X2	X2, N Fork Rose Cr	17-May-06	34	4.85	0.042
X2	X2, N Fork Rose Cr	19-Jun-06	60	8.95	0.017
X2	X2, N Fork Rose Cr	18-Jul-06	79	11.7	0.02
X2	X2, N Fork Rose Cr	21-Aug-06	87	12.2	0.023
X2	X2, N Fork Rose Cr	11-Sep-06	82	12.8	0.023
X2	X2, N Fork Rose Cr	16-Oct-06	124	27.4	0.065
X2	X2, N Fork Rose Cr	14-Nov-06	146	31.1	0.064
X2	X2, N Fork Rose Cr	18-Apr-07	170	33.7	0.18
X2	X2, N Fork Rose Cr	14-May-07	67	12.8	0.068
X2	X2, N Fork Rose Cr	18-Jun-07	61	9.25	0.029
X2	X2, N Fork Rose Cr	16-Jul-07	59	10.1	0.025
X2	X2, N Fork Rose Cr	13-Aug-07	90	15.3	0.031
X2	X2, N Fork Rose Cr	10-Sep-07	73	14.2	0.025
X2	X2, N Fork Rose Cr	22-Oct-07	110	19.9	0.063
X2	X2, N Fork Rose Cr	13-Nov-07	127	24.5	0.068
X2	X2, N Fork Rose Cr	09-Dec-07	130	28.1	0.097
n			31	31	31
minimum			33.0	4.0	0.015
maximum			187	39.7	0.180
median			108.0	16.6	0.035
mean			111	21.1	0.048
standard deviation			45.4	11.1	0.037
standard error			8.15	1.99	0.007
# < detection limit			0	0	0
% <detection limit			0	0	0
# >criterion			-	0	20
% >criterion			-	0	65
99th percentile			186	39.4	0.168
95th percentile			179	38.0	0.119
90th percentile			170	37.2	0.094
water quality criterion			-	50	0.03

Table A.1: Hardness, sulphate and zinc data collected at Faro Stations, 2005 - 2007

Station	Name	Date	Hardness (mg/L)	Sulphate (mg/L)	Zinc - total (mg/L)
R2	R2	29-Mar-05	361	154	0.023
R2	R2	17-Aug-05	212	114	0.045
R2	R2	21-Feb-06	343	202	0.052
R2	R2	08-Aug-06	158	88.2	0.022
R2	R2	20-Feb-07	425	288	0.031
R2	R2	17-Aug-07	207	150	0.033
n			6	6	6
minimum			158.0	88.2	0.022
maximum			425	288	0.052
median			278	152.0	0.032
mean			284	166.0	0.034
standard deviation			106	71.2	0.012
standard error			43.3	29.1	0.005
# < detection limit			0	0	0
% <detection limit			0	0	0
# >criterion			-	6	4
% >criterion			-	100	67
99th percentile			422	283.7	0.052
95th percentile			409	267	0.050
90th percentile			393	245	0.049
water quality criterion			-	50	0.03

Table A.1: Hardness, sulphate and zinc data collected at Faro Stations, 2005 - 2007

Station	Name	Date	Hardness (mg/L)	Sulphate (mg/L)	Zinc - total (mg/L)
R3	R3	29-Mar-05	334	133	0.01
R3	R3	17-Aug-05	188	91.3	0.034
R3	R3	21-Feb-06	272	143	0.022
R3	R3	07-Aug-06	160	81.3	0.017
R3	R3	20-Feb-07	327	187	0.017
R3	R3	17-Aug-07	189	131	0.019
R3	R3	26-Sep-07	118	33	0.0221
R3	R3	24-Oct-07	276	170	0.0427
R3	R3	22-Nov-07	187	74.7	0.0274
R3	R3	14-Dec-07	212	85.7	0.0268
n			10	10	10
minimum			118.0	33.0	0.0100
maximum			334	187	0.0427
median			201	111.15	0.022
mean			226	113	0.024
standard deviation			72	47.7	0.009
standard error			22.9	15.1	0.003
# < detection limit			0	0	0
% <detection limit			0	0	0
# >criterion			-	9	2
% >criterion			-	90	20
99th percentile			333	185	0.042
95th percentile			331	179	0.039
90th percentile			328	172	0.035
water quality criterion			-	50	0.03

Table A.1: Hardness, sulphate and zinc data collected at Faro Stations, 2005 - 2007

Station	Name	Date	Hardness (mg/L)	Sulphate (mg/L)	Zinc - total (mg/L)
R4	Rose Ck u/s Anvil Ck	29-Mar-05	258	81.6	< 0.005
R4	Rose Ck u/s Anvil Ck	17-Aug-05	184	77.6	0.025
R4	Rose Ck u/s Anvil Ck	21-Feb-06	250	127	0.005
R4	Rose Ck u/s Anvil Ck	07-Aug-06	150	74.9	0.011
R4	Rose Ck u/s Anvil Ck	20-Feb-07	262	126	< 0.005
R4	Rose Ck u/s Anvil Ck	17-Aug-07	180	113	0.012
R4	Rose Ck u/s Anvil Ck	26-Sep-07	117	26.4	0.0156
R4	Rose Ck u/s Anvil Ck	24-Oct-07	233	125	0.0244
R4	Rose Ck u/s Anvil Ck	22-Nov-07	181	69.6	0.0147
R4	Rose Ck u/s Anvil Ck	14-Dec-07	213	77.6	0.0131
n			10	10	10
minimum			117.0	26.4	0.0025
maximum			262	127	0.025
median			199	79.6	0.0126
mean			203	89.9	0.0126
standard deviation			49	32.5	0.0080
standard error			15.4	10.3	0.0025
# < detection limit			0	0	2
% <detection limit			0	0	20
# >criterion			-	9	0
% >criterion			-	90	0
99th percentile			262	127	0.0249
95th percentile			260	127	0.0247
90th percentile			258	126	0.0245
water quality criterion			-	50	0.03

Table A.1: Hardness, sulphate and zinc data collected at Faro Stations, 2005 - 2007

Station	Name	Date	Hardness (mg/L)	Sulphate (mg/L)	Zinc - total (mg/L)
R5	Anvil Ck d/s Rose Ck	29-Mar-05	272	80.3	0.007
R5	Anvil Ck d/s Rose Ck	17-Aug-05	159	27.9	< 0.005
R5	Anvil Ck d/s Rose Ck	07-Aug-06	141	21.7	< 0.005
R5	Anvil Ck d/s Rose Ck	17-Aug-07	135	25.2	< 0.005
n			4	4	4
minimum			135	21.7	0.0025
maximum			272	80.3	0.0070
median			150	26.6	0.0025
mean			177	38.8	0.0036
standard deviation			64.3	27.8	0.0023
standard error			32.2	13.90	0.0011
# < detection limit			0	0	3
% <detection limit			0	0	75
# >criterion			-	1	0
% >criterion			-	25	0
99th percentile			269	78.7	0.0069
95th percentile			255	72.4	0.0063
90th percentile			238	64.6	0.0057
water quality criterion			-	50	0.03

Table A.1: Hardness, sulphate and zinc data collected at Faro Stations, 2005 - 2007

Station	Name	Date	Hardness (mg/L)	Sulphate (mg/L)	Zinc - total (mg/L)
A1	A1	26-Sep-07	125	33.3	0.0076
A1	A1	24-Oct-07	176	59.2	0.0027
A1	A1	22-Nov-07	165	44.8	0.002
A1	A1	14-Dec-07	170	43.5	0.0022
A1	A1	23-Jan-08	180	60.6	0.0013
A1	A1	20-Feb-08	186	55	0.0012
A1	A1	13-Mar-08	189	53.4	0.0046
A1	A1	28-Apr-08	224	88	0.0073
A1	A1	21-May-08	70.5	18	0.0229
A1	A1	24-Jun-08	68.3	19	0.0238
A1	A1	17-Sep-08	119	34	0.0061
A1	A1	08-Oct-08	127	34	0.0001
A1	A1	10-Dec-08	163	40	0.0048
A1	A1	24-Feb-09	188	50	0.0099
A1	A1	26-Mar-09	180	58	0.0017
A1	A1	20-May-09	113	43	0.0114
A1	A1	23-Jun-09	112	30	0.0001
n			17	17	17
minimum			68.3	18	0.0001
maximum			224	88	0.0238
median			165	43.5	0.0046
mean			150.3	44.93	0.0065
standard deviation			44.0	17.14	0.0072
standard error			10.7	4.16	0.0017
# < detection limit			0	0	0
% <detection limit			0	0	0
# >criterion			-	6	0
% >criterion			-	35%	0%
99th percentile			218	83.6	0.0237
95th percentile			196	66.1	0.0231
90th percentile			188	59.8	0.0160
water quality criterion			-	50	0.030

Table A.1: Hardness, sulphate and zinc data collected at Faro Stations, 2005 - 2007

Station	Name	Date	Hardness (mg/L)	Sulphate (mg/L)	Zinc - total (mg/L)
X14	X14, Rose Cr	21-Jan-05	313	182	0.028
X14	X14, Rose Cr	08-Feb-05	359	165	0.028
X14	X14, Rose Cr	08-Mar-05	639	409	0.25
X14	X14, Rose Cr	14-Mar-05	717	541	0.19
X14	X14, Rose Cr	22-Mar-05	793	557	0.2
X14	X14, Rose Cr	11-Apr-05	315	145	0.019
X14	X14, Rose Cr	10-May-05	74	34.3	0.035
X14	X14, Rose Cr	31-May-05	94	40.7	0.019
X14	X14, Rose Cr	11-Jun-05	100	45.2	0.017
X14	X14, Rose Cr	19-Jun-05	133	64.2	0.022
X14	X14, Rose Cr	21-Jun-05	140	77.1	0.027
X14	X14, Rose Cr	02-Jul-05	153	86.1	0.011
X14	X14, Rose Cr	10-Jul-05	154	89.7	0.029
X14	X14, Rose Cr	17-Jul-05	169	91.6	0.035
X14	X14, Rose Cr	24-Jul-05	160	79.7	0.032
X14	X14, Rose Cr	25-Jul-05	143	71.4	0.024
X14	X14, Rose Cr	31-Jul-05	132	65.4	0.029
X14	X14, Rose Cr	06-Aug-05	170	88.9	0.037
X14	X14, Rose Cr	13-Aug-05	206	111	0.051
X14	X14, Rose Cr	20-Aug-05	195	109	0.051
X14	X14, Rose Cr	23-Aug-05	206	109	0.05
X14	X14, Rose Cr	27-Aug-05	173	97.7	0.049
X14	X14, Rose Cr	05-Sep-05	202		0.06
X14	X14, Rose Cr	06-Sep-05	203	136	0.057
X14	X14, Rose Cr	11-Sep-05	198		0.05
X14	X14, Rose Cr	18-Sep-05	187		0.03
X14	X14, Rose Cr	24-Sep-05	174		0.034
X14	X14, Rose Cr	01-Oct-05	209	129	0.066
X14	X14, Rose Cr	11-Oct-05	142	41.4	0.028
X14	X14, Rose Cr	02-Nov-05	187	67	0.043
X14	X14, Rose Cr	15-Dec-05	250	111	0.056
X14	X14, Rose Cr	23-Jan-06	306	181	0.062
X14	X14, Rose Cr	14-Feb-06	361	254	0.04
X14	X14, Rose Cr	24-Mar-06	407	259	0.044
X14	X14, Rose Cr	25-Apr-06	348	225	0.045
X14	X14, Rose Cr	09-May-06	446	339	0.17
X14	X14, Rose Cr	18-May-06	55	16.8	0.03
X14	X14, Rose Cr	23-May-06	69	34.5	0.035
X14	X14, Rose Cr	30-May-06	106	56.8	0.028
X14	X14, Rose Cr	06-Jun-06	89	43.6	0.022
X14	X14, Rose Cr	19-Jun-06	130	63.5	0.027
X14	X14, Rose Cr	20-Jun-06	144	73.5	0.026
X14	X14, Rose Cr	11-Jul-06	135	70.9	0.016
X14	X14, Rose Cr	17-Jul-06	168	107	0.023
X14	X14, Rose Cr	18-Jul-06	174	109	0.033
X14	X14, Rose Cr	25-Jul-06	203	137	0.028
X14	X14, Rose Cr	01-Aug-06	187	104	0.023
X14	X14, Rose Cr	15-Aug-06	143	94.7	0.028
X14	X14, Rose Cr	21-Aug-06	147	82.2	0.026
X14	X14, Rose Cr	22-Aug-06	147	83.3	0.027
X14	X14, Rose Cr	29-Aug-06	182	117	0.039
X14	X14, Rose Cr	05-Sep-06	141	64.9	0.025
X14	X14, Rose Cr	12-Sep-06	109	32.8	0.018
X14	X14, Rose Cr	17-Oct-06	172	65.4	0.032
X14	X14, Rose Cr	14-Nov-06	230	111	0.055
X14	X14, Rose Cr	13-Dec-06	288	164	0.06
X14	X14, Rose Cr	16-Jan-07	354	225	0.053
X14	X14, Rose Cr	15-Feb-07	409	273	0.031
X14	X14, Rose Cr	12-Mar-07	547	420	0.024
X14	X14, Rose Cr	10-Apr-07	812	704	0.22
X14	X14, Rose Cr	19-Apr-07	363	216	0.07
X14	X14, Rose Cr	14-May-07	97	31.1	0.043
X14	X14, Rose Cr	15-May-07	98	29.4	0.045
X14	X14, Rose Cr	22-May-07	88	46	0.034
X14	X14, Rose Cr	29-May-07	84	42.9	0.016
X14	X14, Rose Cr	05-Jun-07	54	22.9	0.014
X14	X14, Rose Cr	12-Jun-07	75	31.4	0.016
X14	X14, Rose Cr	18-Jun-07	99	66	0.019

Table A.1: Hardness, sulphate and zinc data collected at Faro Stations, 2005 - 2007

Station	Name	Date	Hardness (mg/L)	Sulphate (mg/L)	Zinc - total (mg/L)
X14	X14, Rose Cr	19-Jun-07	139	82.6	0.019
X14	X14, Rose Cr	26-Jun-07	102	45.6	0.02
X14	X14, Rose Cr	03-Jul-07	108	53.6	0.019
X14	X14, Rose Cr	10-Jul-07	165	99.3	0.066
X14	X14, Rose Cr	16-Jul-07	134	68	0.025
X14	X14, Rose Cr	17-Jul-07	112	135	0.023
X14	X14, Rose Cr	24-Jul-07	215	110	0.031
X14	X14, Rose Cr	31-Jul-07	191	111	0.022
X14	X14, Rose Cr	07-Aug-07	177	118	0.026
X14	X14, Rose Cr	13-Aug-07	235	158	0.033
X14	X14, Rose Cr	14-Aug-07	191	121	0.032
X14	X14, Rose Cr	21-Aug-07	217	163	0.037
X14	X14, Rose Cr	28-Aug-07	197	117	0.034
X14	X14, Rose Cr	04-Sep-07	195	132	0.038
X14	X14, Rose Cr	10-Sep-07	175	122	0.038
X14	X14, Rose Cr	11-Sep-07	154	78.4	0.033
X14	X14, Rose Cr	17-Sep-07	142	81.1	0.027
X14	X14, Rose Cr	25-Sep-07	117	36.6	0.0225
X14	X14, Rose Cr	23-Oct-07	322	219	0.07
X14	X14, Rose Cr	25-Oct-07	333	248	0.0789
X14	X14, Rose Cr	29-Oct-07	263	183	0.069
X14	X14, Rose Cr	14-Nov-07	203	81.5	0.051
X14	X14, Rose Cr	21-Nov-07	212	89.7	0.0508
X14	X14, Rose Cr	10-Dec-07	246	135	0.052
X14	X14, Rose Cr	13-Dec-07	279	119	0.0517
n			93	89	93
minimum			54.0	16.8	0.011
maximum			812	704	0.250
median			175	99.3	0.033
mean			216	131	0.045
standard deviation			146	118	0.042
standard error			15.1	12.5	0.004
# < detection limit			0	0	0
% <detection limit			0	0	0.0
# >criterion			-	73	52
% >criterion			-	82	56
99th percentile			795	575	0.222
95th percentile			486	381	0.115
90th percentile			361	249.2	0.066
water quality criterion			-	50	0.03

Table A.1: Hardness, sulphate and zinc data collected at Faro Stations, 2005 - 2007

Station	Name	Date	Hardness (mg/L)	Sulphate (mg/L)	Zinc - total (mg/L)
P2	P2	27-Sep-07	153	54.5	0.0179
P2	P2	24-Oct-07	176	62.9	0.0149
P2	P2	22-Nov-07	214	68.2	0.0174
P2	P2	14-Dec-07	213	62.6	0.0238
P2	P2	24-Jan-08	217	65.7	0.0173
P2	P2	20-Feb-08	225	69.8	0.0159
P2	P2	12-Mar-08	218	66.6	0.0181
P2	P2	28-Apr-08	209	61	0.0136
P2	P2	21-May-08	95.1	31	0.0348
P2	P2	24-Jun-08	145	43	0.0401
P2	P2	29-Jul-08	143	52	0.0116
P2	P2	17-Sep-08	147	50	0.0229
P2	P2	08-Oct-08	146	44	0.0001
P2	P2	10-Dec-08	202	50	0.0079
P2	P2	24-Feb-09	221	63	0.0027
P2	P2	26-Mar-09	202	72	0.0152
P2	P2	20-May-09	118	49	0.0153
P2	P2	23-Jun-09	121	37	0.0002
n			18	18	18
minimum			95.1	31	0.0001
maximum			225	72	0.0401
median			189	57.75	0.0156
mean			175.8	55.68	0.0161
standard deviation			42.3	11.89	0.0104
standard error			10.0	2.80	0.0024
# < detection limit			0	0	0
% <detection limit			0	0	0
# >criterion			-	11	2
% >criterion			-	61%	11%
99th percentile			224	71.6	0.0392
95th percentile			222	70.1	0.0356
90th percentile			219	68.7	0.0271
water quality criterion			-	50	0.030

Table A.1: Hardness, sulphate and zinc data collected at Faro Stations, 2005 - 2007

Station	Name	Date	Hardness (mg/L)	Sulphate (mg/L)	Zinc - total (mg/L)
P4	P4	26-Sep-07	142	45.4	0.014
P4	P4	24-Oct-07	173	60.1	0.0107
P4	P4	22-Nov-07	187	61.2	0.0078
P4	P4	14-Dec-07	209	61.1	0.0175
P4	P4	23-Jan-08	212	62.2	0.0152
P4	P4	20-Feb-08	214	67.3	0.0128
P4	P4	13-Mar-08	216	64.1	0.0156
P4	P4	28-Apr-08	200	61	0.0116
P4	P4	21-May-08	104	29	0.0458
P4	P4	24-Jun-08	117	37	0.0267
P4	P4	29-Jul-08	136	44	0.0076
P4	P4	17-Sep-08	136	40	0.0142
P4	P4	08-Oct-08	153	50	0.0001
P4	P4	10-Dec-08	200	58	0.026
P4	P4	24-Feb-09	196	36	0.0022
P4	P4	26-Mar-09	199	69	0.0113
P4	P4	20-May-09	121	48	0.0148
P4	P4	23-Jun-09	126	36	0.0002
n			18	18	18
minimum			104	29	0.0001
maximum			216	69	0.0458
median			180	54	0.0134
mean			168.9	51.6	0.0141
standard deviation			39.0	12.5	0.0107
standard error			9.2	2.95	0.0025
# < detection limit			0	0	0
% <detection limit			0	0	0
# >criterion			-	9	1
% >criterion			-	50%	6%
99th percentile			216	68.7	0.0426
95th percentile			214	67.6	0.0296
90th percentile			213	65.1	0.0262
water quality criterion			-	50	0.030

Table A.1: Hardness, sulphate and zinc data collected at Faro Stations, 2005 - 2007

Station	Name	Date	Hardness (mg/L)	Sulphate (mg/L)	Zinc - total (mg/L)
V27	V27	26-May-05	57	28.5	0.031
V27	V27	21-Sep-05	84	48.5	0.017
V27	V27	29-May-06	55	25.3	0.022
V27	V27	01-Aug-06	110	56.4	0.018
V27	V27	26-Sep-06	94	52	0.023
V27	V27	04-Jun-07	17	8.46	0.016
V27	V27	25-Jul-07	100	47.5	0.031
V27	V27	28-Aug-07		49.3	0.0318
V27	V27	26-Sep-07	92	50.2	0.0257
V27	V27	10-Oct-07	108	64.1	0.026
V27	V27	24-Oct-07	148	85.5	0.0253
V27	V27	22-Nov-07	201	99	0.0274
V27	V27	14-Dec-07	209	106	0.0262
n			12	13	13
minimum			17	8.46	0.016
maximum			209	106	0.0318
median			97	50.2	0.0257
mean			106.3	55.4	0.0246
standard deviation			56.6	28.1	0.0053
standard error			16.3	7.79	0.0015
# < detection limit			0	0	0
% <detection limit			0	0	0
# >criterion			-	7	3
% >criterion			-	54%	23%
99th percentile			208	105.2	0.0317
95th percentile			205	101.8	0.0313
90th percentile			196	96.3	0.0310
water quality criterion			-	50	0.030

Table A.2: Hardness and cadmium and data collected at Faro Stations, 2005 - 2008

Station	Name	Date	Hardness (mg/L)	Cadmium - total (mg/L)
V8	Vagorda Ck in Faro	21-Jan-05	373	<0.0002
V8	Vagorda Ck in Faro	08-Feb-05	374	<0.0002
V8	Vagorda Ck in Faro	15-Mar-05	395	<0.0002
V8	Vagorda Ck in Faro	11-Apr-05	382	<0.0002
V8	Vagorda Ck in Faro	09-May-05	116	<0.0002
V8	Vagorda Ck in Faro	20-Jun-05	214	<0.0002
V8	Vagorda Ck in Faro	25-Jul-05	321	<0.0002
V8	Vagorda Ck in Faro	22-Aug-05	449	<0.0002
V8	Vagorda Ck in Faro	05-Sep-05	210	<0.0002
V8	Vagorda Ck in Faro	10-Oct-05	237	<0.0002
V8	Vagorda Ck in Faro	01-Nov-05	275	<0.0002
V8	Vagorda Ck in Faro	14-Dec-05	328	<0.0002
V8	Vagorda Ck in Faro	24-Jan-06	384	<0.0002
V8	Vagorda Ck in Faro	13-Feb-06	381	<0.0002
V8	Vagorda Ck in Faro	24-Mar-06	402	<0.0002
V8	Vagorda Ck in Faro	24-Apr-06	356	<0.0002
V8	Vagorda Ck in Faro	17-May-06	143	<0.0002
V8	Vagorda Ck in Faro	19-Jun-06	118	<0.0002
V8	Vagorda Ck in Faro	17-Jul-06	143	<0.0002
V8	Vagorda Ck in Faro	21-Aug-06	309	<0.002
V8	Vagorda Ck in Faro	21-Aug-06	174	<0.0002
V8	Vagorda Ck in Faro	11-Sep-06	166	<0.0002
V8	Vagorda Ck in Faro	16-Oct-06	230	<0.0002
V8	Vagorda Ck in Faro	14-Nov-06	312	<0.0002
V8	Vagorda Ck in Faro	13-Dec-06	328	<0.0002
V8	Vagorda Ck in Faro	15-Jan-07	362	<0.0002
V8	Vagorda Ck in Faro	13-Feb-07	369	<0.0002
V8	Vagorda Ck in Faro	11-Mar-07	410	<0.0002
V8	Vagorda Ck in Faro	18-Apr-07	371	<0.0002
V8	Vagorda Ck in Faro	14-May-07	197	<0.0002
V8	Vagorda Ck in Faro	18-Jun-07	112	<0.0002
V8	Vagorda Ck in Faro	16-Jul-07	133	<0.0002
V8	Vagorda Ck in Faro	13-Aug-07	202	<0.0002
V8	Vagorda Ck in Faro	27-Aug-07		0.00004
V8	Vagorda Ck in Faro	27-Aug-07		0.00004
V8	Vagorda Ck in Faro	10-Sep-07	180	<0.0002
V8	Vagorda Ck in Faro	23-Oct-07	260	<0.0002
V8	Vagorda Ck in Faro	13-Nov-07	282	<0.0002
V8	Vagorda Ck in Faro	09-Dec-07	293	<0.0002
V8	Vagorda Ck in Faro	07-Jan-08	298	<0.0002
V8	Vagorda Ck in Faro	18-Feb-08	368	<0.0002
V8	Vagorda Ck in Faro	17-Mar-08	398	<0.0002
V8	Vagorda Ck in Faro	14-Apr-08	390	<0.0002
V8	Vagorda Ck in Faro	14-May-08	180	<0.0002
V8	Vagorda Ck in Faro	26-May-08	88.8	0.000219
V8	Vagorda Ck in Faro	16-Jun-08	143	<0.0002
V8	Vagorda Ck in Faro	14-Jul-08	169	<0.0002
V8	Vagorda Ck in Faro	11-Aug-08	278	<0.0002
V8	Vagorda Ck in Faro	15-Sep-08	175	<0.0002
V8	Vagorda Ck in Faro	15-Oct-08	227	<0.0002
V8	Vagorda Ck in Faro	03-Nov-08	300	0.0002
V8	Vagorda Ck in Faro	01-Dec-08	392	<0.0002
V8	Vagorda Ck in Faro	12-Jan-09	399	<0.0002
V8	Vagorda Ck in Faro	02-Feb-09	414	<0.0002
V8	Vagorda Ck in Faro	3-Mar-09	471	0.000074
V8	Vagorda Ck in Faro	6-Apr-09	435	0.000067
V8	Vagorda Ck in Faro	6-May-09	122	0.000282
V8	Vagorda Ck in Faro	10-Jun-09	118	0.000038
n			56	7
minimum			88.8	0.000038
maximum			471	0.000282
median			295.5	0.000074
mean			279.6	0.00013
standard deviation			108.2	0.00010
standard error			14.5	0.00004
# < detection limit			0	0
% <detection limit			0	0
# >criterion			-	7
% >criterion			-	100%
99th percentile			459	0.0003
95th percentile			419	0.0003
90th percentile			401	0.0002
water quality criterion			-	0.00003

Shaded values not included in summary statistics

Table A.2: Hardness and cadmium and data collected at Faro Stations, 2005 - 2008

Station	Name	Date	Hardness (mg/L)	Cadmium - total (mg/L)
X2	X2, N Fork Rose Cr	21-Jan-05	173	<0.0002
X2	X2, N Fork Rose Cr	08-Feb-05	187	<0.0002
X2	X2, N Fork Rose Cr	15-Mar-05	163	<0.0002
X2	X2, N Fork Rose Cr	11-Apr-05	158	<0.0002
X2	X2, N Fork Rose Cr	09-May-05	33	<0.0002
X2	X2, N Fork Rose Cr	20-Jun-05	74	<0.0002
X2	X2, N Fork Rose Cr	25-Jul-05	73	<0.0002
X2	X2, N Fork Rose Cr	22-Aug-05	108	<0.0002
X2	X2, N Fork Rose Cr	05-Sep-05	92	<0.0002
X2	X2, N Fork Rose Cr	10-Oct-05	96	<0.0002
X2	X2, N Fork Rose Cr	01-Nov-05	121	<0.0002
X2	X2, N Fork Rose Cr	13-Dec-05	146	<0.0002
X2	X2, N Fork Rose Cr	23-Jan-06	185	<0.0002
X2	X2, N Fork Rose Cr	14-Feb-06	163	<0.0002
X2	X2, N Fork Rose Cr	24-Apr-06	163	<0.0002
X2	X2, N Fork Rose Cr	17-May-06	34	<0.0002
X2	X2, N Fork Rose Cr	19-Jun-06	60	<0.0002
X2	X2, N Fork Rose Cr	18-Jul-06	79	<0.0002
X2	X2, N Fork Rose Cr	21-Aug-06	87	<0.0002
X2	X2, N Fork Rose Cr	11-Sep-06	82	<0.0002
X2	X2, N Fork Rose Cr	16-Oct-06	124	<0.0002
X2	X2, N Fork Rose Cr	14-Nov-06	146	<0.0002
X2	X2, N Fork Rose Cr	18-Apr-07	170	<0.0002
X2	X2, N Fork Rose Cr	14-May-07	67	<0.0002
X2	X2, N Fork Rose Cr	18-Jun-07	61	<0.0002
X2	X2, N Fork Rose Cr	16-Jul-07	59	<0.0002
X2	X2, N Fork Rose Cr	13-Aug-07	90	0.0002
X2	X2, N Fork Rose Cr	10-Sep-07	73	<0.0002
X2	X2, N Fork Rose Cr	22-Oct-07	110	<0.0002
X2	X2, N Fork Rose Cr	13-Nov-07	127	<0.0002
X2	X2, N Fork Rose Cr	09-Dec-07	130	<0.0002
X2	X2, N Fork Rose Cr	07-Jan-08	119	<0.0002
X2	X2, N Fork Rose Cr	18-Feb-08	168	<0.0002
X2	X2, N Fork Rose Cr	17-Mar-08	151	<0.0002
X2	X2, N Fork Rose Cr	14-Apr-08	162	<0.0002
X2	X2, N Fork Rose Cr	14-May-08	41	<0.0002
X2	X2, N Fork Rose Cr	12-Jun-08	48.5	0.00003
X2	X2, N Fork Rose Cr	16-Jun-08	68	<0.0002
X2	X2, N Fork Rose Cr	14-Jul-08	54	<0.0002
X2	X2, N Fork Rose Cr	22-Jul-08	63.9	0.000026
X2	X2, N Fork Rose Cr	11-Aug-08	78	<0.0002
X2	X2, N Fork Rose Cr	19-Aug-08	80.2	0.000018
X2	X2, N Fork Rose Cr	25-Aug-08	53.2	0.000074
X2	X2, N Fork Rose Cr	15-Sep-08	68	<0.0002
X2	X2, N Fork Rose Cr	15-Oct-08	85	<0.0002
X2	X2, N Fork Rose Cr	03-Nov-08	116	0.0003
X2	X2, N Fork Rose Cr	01-Dec-08	139	<0.0002
n			47	5
minimum			33.0	0.000018
maximum			187	0.0002
median			92.0	0.00003
mean			105	0.0001
standard deviation			44.8	0.0001
standard error			6.53	0.00003
# < detection limit			0	-1
% <detection limit			0	-20
# >criterion			-	2
% >criterion			-	40
99th percentile			186	0.0002
95th percentile			172	0.0002
90th percentile			165	0.0001
water quality criterion			-	0.00003

Shaded values not included in summary statistics

Table A.2: Hardness and cadmium and data collected at Faro Stations, 2005 - 2008

Station	Name	Date	Hardness (mg/L)	Cadmium - total (mg/L)
R2	R2	29-Mar-05	361	<0.0002
R2	R2	17-Aug-05	212	<0.0002
R2	R2	21-Feb-06	343	<0.0002
R2	R2	08-Aug-06	158	<0.0002
R2	R2	20-Feb-07	425	<0.0002
R2	R2	17-Aug-07	207	<0.0002
R2	R2	03-Mar-08	452	<0.0002
R2	R2	21-Jul-08	110	0.000022
R2	R2	19-Aug-08	156	<0.0002
R2	R2	20-Aug-08	166	0.000023
R2	R2	25-Aug-08	82.2	0.000078
n			11	3
minimum			82.2	0.000022
maximum			452	0.00008
median			207	0.00002
mean			243	0.00004
standard deviation			129	0.00003
standard error			39.0	0.00002
# < detection limit			0	0
% <detection limit			0	0
# >criterion			-	1
% >criterion			-	33
99th percentile			449	0.00008
95th percentile			439	0.00007
90th percentile			425	0.00007
water quality criterion			-	0.00003

Shaded values not included in summary statistics

Table A.2: Hardness and cadmium and data collected at Faro Stations, 2005 - 2008

Station	Name	Date	Hardness (mg/L)	Cadmium - total (mg/L)
R3	R3	29-Mar-05	334	<0.0002
R3	R3	17-Aug-05	188	<0.0002
R3	R3	21-Feb-06	272	<0.0002
R3	R3	07-Aug-06	160	<0.0002
R3	R3	20-Feb-07	327	<0.0002
R3	R3	17-Aug-07	189	<0.0002
R3	R3	26-Sep-07	118	0.00002
R3	R3	24-Oct-07	276	0.000046
R3	R3	22-Nov-07	187	0.000032
R3	R3	14-Dec-07	212	0.000026
R3	R3	23-Jan-08	254	0.000102
R3	R3	20-Feb-08	301	0.000014
R3	R3	04-Mar-08	346	<0.0002
R3	R3	13-Mar-08	311	0.000015
R3	R3	28-Apr-08	495	0.000067
R3	R3	21-May-08	79.9	0.000082
R3	R3	24-Jun-08	58.6	0.000089
R3	R3	22-Jul-08	107	0.000022
R3	R3	29-Jul-08	136	0.000022
R3	R3	19-Aug-08	147	<0.0002
R3	R3	04-Sep-08	142	0.000024
R3	R3	17-Sep-08	134	0.00003
R3	R3	08-Oct-08	149	0.00005
R3	R3	10-Dec-08	190	0.000028
n			24	16
minimum			58.6	0.000014
maximum			495	0.000102
median			189	0.000029
mean			213	0.00004
standard deviation			103	0.00003
standard error			21.0	0.00001
# < detection limit			0	0
% <detection limit			0	0
# >criterion			-	7
% >criterion			-	44
99th percentile			461	0.00010
95th percentile			344	0.00009
90th percentile			332	0.00009
water quality criterion			-	0.00003

Shaded values not included in summary statistics

Table A.2: Hardness and cadmium and data collected at Faro Stations, 2005 - 2008

Station	Name	Date	Hardness (mg/L)	Cadmium - total (mg/L)
R4	Rose Ck u/s Anvil Ck	29-Mar-05	258	<0.0002
R4	Rose Ck u/s Anvil Ck	17-Aug-05	184	<0.0002
R4	Rose Ck u/s Anvil Ck	21-Feb-06	250	<0.0002
R4	Rose Ck u/s Anvil Ck	07-Aug-06	150	<0.0002
R4	Rose Ck u/s Anvil Ck	20-Feb-07	262	<0.0002
R4	Rose Ck u/s Anvil Ck	17-Aug-07	180	<0.0002
R4	Rose Ck u/s Anvil Ck	26-Sep-07	117	0.00001
R4	Rose Ck u/s Anvil Ck	24-Oct-07	233	0.00006
R4	Rose Ck u/s Anvil Ck	22-Nov-07	181	0.000022
R4	Rose Ck u/s Anvil Ck	14-Dec-07	213	0.00002
R4	Rose Ck u/s Anvil Ck	23-Jan-08	261	0.000011
R4	Rose Ck u/s Anvil Ck	20-Feb-08	262	0.000007
R4	Rose Ck u/s Anvil Ck	04-Mar-08	300	<0.0002
R4	Rose Ck u/s Anvil Ck	13-Mar-08	276	0.000025
R4	Rose Ck u/s Anvil Ck	28-Apr-08	400	0.000057
R4	Rose Ck u/s Anvil Ck	21-May-08	78	0.000046
R4	Rose Ck u/s Anvil Ck	24-Jun-08	60.6	0.000139
R4	Rose Ck u/s Anvil Ck	22-Jul-08	110	0.000026
R4	Rose Ck u/s Anvil Ck	29-Jul-08	136	0.000022
R4	Rose Ck u/s Anvil Ck	19-Aug-08	142	<0.0002
R4	Rose Ck u/s Anvil Ck	04-Sep-08	135	0.00003
R4	Rose Ck u/s Anvil Ck	17-Sep-08	133	0.000032
R4	Rose Ck u/s Anvil Ck	08-Oct-08	142	0.000036
R4	Rose Ck u/s Anvil Ck	10-Dec-08	190	0.000018
R4	Rose Ck u/s Anvil Ck	24-Feb-09	155	0.00004
R4	Rose Ck u/s Anvil Ck	26-Mar-09	256	0.000014
R4	Rose Ck u/s Anvil Ck	20-May-09	129	0.000055
R4	Rose Ck u/s Anvil Ck	23-Jun-09	133	0.000031
n			28	20
minimum			60.6	0.000007
maximum			400	0.000139
median			180.5	0.000028
mean			190.2	0.00004
standard deviation			76.7	0.00003
standard error			14.5	0.000006
# < detection limit			0	0
% <detection limit			0	0
# >criterion			-	9
% >criterion			-	45%
99th percentile			373	0.000124
95th percentile			292	0.000064
90th percentile			266	0.000057
water quality criterion			-	0.00003

Shaded values not included in summary statistics

Table A.2: Hardness and cadmium and data collected at Faro Stations, 2005 - 2008

Station	Name	Date	Hardness (mg/L)	Cadmium - total (mg/L)
R5	Anvil Ck d/s Rose Ck	29-Mar-05	272	<0.0002
R5	Anvil Ck d/s Rose Ck	17-Aug-05	159	<0.0002
R5	Anvil Ck d/s Rose Ck	07-Aug-06	141	<0.0002
R5	Anvil Ck d/s Rose Ck	17-Aug-07	135	<0.0002
R5	Anvil Ck d/s Rose Ck	04-Mar-08	209	<0.0002
R5	Anvil Ck d/s Rose Ck	22-Jul-08	116	0.000019
R5	Anvil Ck d/s Rose Ck	19-Aug-08	141	<0.0002
R5	Anvil Ck d/s Rose Ck	04-Sep-08	131	0.000019
n			8	2
minimum			116	0.000019
maximum			272	0.000019
median			141	0.000019
mean			163	0.000019
standard deviation			52.1	0.000000
standard error			18.4	0.000000
# < detection limit			0	0
% <detection limit			0	0
# >criterion			-	0
% >criterion			-	0
99th percentile			268	0.000019
95th percentile			250	0.000019
90th percentile			228	0.000019
water quality criterion			-	0.00003

Shaded values not included in summary statistics

Table A.2: Hardness and cadmium and data collected at Faro Stations, 2005 - 2008

Station	Name	Date	Hardness (mg/L)	Cadmium - total (mg/L)
A1	A1	26-Sep-07	125	0.00001
A1	A1	24-Oct-07	176	0.000025
A1	A1	22-Nov-07	165	0.000013
A1	A1	14-Dec-07	170	0.000027
A1	A1	23-Jan-08	180	0.000006
A1	A1	20-Feb-08	186	0.000011
A1	A1	13-Mar-08	189	0.00001
A1	A1	28-Apr-08	224	0.000045
A1	A1	21-May-08	70.5	0.00012
A1	A1	24-Jun-08	68.3	0.00017
A1	A1	17-Sep-08	119	0.000037
A1	A1	08-Oct-08	127	0.000022
A1	A1	10-Dec-08	163	0.000017
A1	A1	24-Feb-09	188	0.000084
A1	A1	26-Mar-09	180	0.00002
A1	A1	20-May-09	113	0.000088
A1	A1	23-Jun-09	112	0.000028
n			17	17
minimum			68.3	0.000006
maximum			224	0.00017
median			165	0.000025
mean			150.3	0.00004
standard deviation			44.0	0.00005
standard error			10.7	0.000011
# < detection limit			0	0
% <detection limit			0	0
# >criterion			-	6
% >criterion			-	35%
99th percentile			218	0.000162
95th percentile			196	0.000130
90th percentile			188	0.000101
water quality criterion			-	0.00003

Shaded values not included in summary statistics

Table A.2: Hardness and cadmium and data collected at Faro Stations, 2005 - 2008

Station	Name	Date	Hardness (mg/L)	Cadmium - total (mg/L)
X14	X14, Rose Cr	21-Jan-05	313	<0.0002
X14	X14, Rose Cr	08-Feb-05	359	<0.0002
X14	X14, Rose Cr	08-Mar-05	639	<0.0002
X14	X14, Rose Cr	14-Mar-05	717	<0.0002
X14	X14, Rose Cr	22-Mar-05	793	<0.0002
X14	X14, Rose Cr	11-Apr-05	315	<0.0002
X14	X14, Rose Cr	10-May-05	74	<0.0002
X14	X14, Rose Cr	31-May-05	94	<0.0002
X14	X14, Rose Cr	11-Jun-05	100	<0.0002
X14	X14, Rose Cr	19-Jun-05	133	<0.0002
X14	X14, Rose Cr	21-Jun-05	140	<0.0002
X14	X14, Rose Cr	02-Jul-05	153	0.0003
X14	X14, Rose Cr	10-Jul-05	154	<0.0002
X14	X14, Rose Cr	17-Jul-05	169	<0.0002
X14	X14, Rose Cr	24-Jul-05	160	<0.0002
X14	X14, Rose Cr	25-Jul-05	143	<0.0002
X14	X14, Rose Cr	31-Jul-05	132	<0.0002
X14	X14, Rose Cr	06-Aug-05	170	<0.0002
X14	X14, Rose Cr	13-Aug-05	206	<0.0002
X14	X14, Rose Cr	20-Aug-05	195	<0.0002
X14	X14, Rose Cr	23-Aug-05	206	<0.0002
X14	X14, Rose Cr	27-Aug-05	173	<0.0002
X14	X14, Rose Cr	05-Sep-05	202	<0.0002
X14	X14, Rose Cr	06-Sep-05	203	<0.0002
X14	X14, Rose Cr	11-Sep-05	198	<0.0002
X14	X14, Rose Cr	18-Sep-05	187	<0.0002
X14	X14, Rose Cr	24-Sep-05	174	<0.0002
X14	X14, Rose Cr	01-Oct-05	209	<0.0002
X14	X14, Rose Cr	11-Oct-05	142	<0.0002
X14	X14, Rose Cr	02-Nov-05	187	<0.0002
X14	X14, Rose Cr	15-Dec-05	250	<0.0002
X14	X14, Rose Cr	23-Jan-06	306	<0.0002
X14	X14, Rose Cr	14-Feb-06	361	<0.0002
X14	X14, Rose Cr	24-Mar-06	407	<0.0002
X14	X14, Rose Cr	25-Apr-06	348	<0.0002
X14	X14, Rose Cr	09-May-06	446	<0.0002
X14	X14, Rose Cr	18-May-06	55	<0.0002
X14	X14, Rose Cr	23-May-06	69	<0.0002
X14	X14, Rose Cr	30-May-06	106	<0.0002
X14	X14, Rose Cr	06-Jun-06	89	<0.0002
X14	X14, Rose Cr	19-Jun-06	130	<0.0002
X14	X14, Rose Cr	20-Jun-06	144	<0.0002
X14	X14, Rose Cr	11-Jul-06	135	<0.0002
X14	X14, Rose Cr	17-Jul-06	168	<0.0002
X14	X14, Rose Cr	18-Jul-06	174	<0.0002
X14	X14, Rose Cr	25-Jul-06	203	<0.0002
X14	X14, Rose Cr	01-Aug-06	187	<0.0002
X14	X14, Rose Cr	15-Aug-06	143	<0.0002
X14	X14, Rose Cr	21-Aug-06	147	<0.0002
X14	X14, Rose Cr	22-Aug-06	147	<0.0002
X14	X14, Rose Cr	29-Aug-06	182	<0.0002
X14	X14, Rose Cr	05-Sep-06	141	<0.0002
X14	X14, Rose Cr	12-Sep-06	109	<0.0002
X14	X14, Rose Cr	17-Oct-06	172	<0.0002
X14	X14, Rose Cr	14-Nov-06	230	<0.0002
X14	X14, Rose Cr	13-Dec-06	288	<0.0002
X14	X14, Rose Cr	16-Jan-07	354	<0.0002
X14	X14, Rose Cr	15-Feb-07	409	<0.0002
X14	X14, Rose Cr	12-Mar-07	547	<0.0002
X14	X14, Rose Cr	10-Apr-07	812	<0.0002
X14	X14, Rose Cr	19-Apr-07	363	<0.0002
X14	X14, Rose Cr	14-May-07	97	<0.0002
X14	X14, Rose Cr	15-May-07	98	<0.0002
X14	X14, Rose Cr	22-May-07	88	<0.0002
X14	X14, Rose Cr	29-May-07	84	<0.0002
X14	X14, Rose Cr	05-Jun-07	54	<0.0002
X14	X14, Rose Cr	12-Jun-07	75	<0.0002

Table A.2: Hardness and cadmium and data collected at Faro Stations, 2005 - 2008

X14	X14, Rose Cr	18-Jun-07	99	<0.0002
X14	X14, Rose Cr	19-Jun-07	139	<0.0002
X14	X14, Rose Cr	26-Jun-07	102	<0.0002
X14	X14, Rose Cr	03-Jul-07	108	<0.0002
X14	X14, Rose Cr	10-Jul-07	165	0.0003
X14	X14, Rose Cr	16-Jul-07	134	<0.0002
X14	X14, Rose Cr	17-Jul-07	112	<0.0002
X14	X14, Rose Cr	24-Jul-07	215	<0.0002
X14	X14, Rose Cr	31-Jul-07	191	<0.0002
X14	X14, Rose Cr	07-Aug-07	177	<0.0002
X14	X14, Rose Cr	13-Aug-07	235	<0.0002
X14	X14, Rose Cr	14-Aug-07	191	<0.0002
X14	X14, Rose Cr	21-Aug-07	217	<0.0002
X14	X14, Rose Cr	28-Aug-07	197	<0.0002
X14	X14, Rose Cr	04-Sep-07	195	0.0002
X14	X14, Rose Cr	10-Sep-07	175	<0.0002
X14	X14, Rose Cr	11-Sep-07	154	<0.0002
X14	X14, Rose Cr	17-Sep-07	142	<0.0002
X14	X14, Rose Cr	25-Sep-07	117	0.00002
X14	X14, Rose Cr	23-Oct-07	322	<0.0002
X14	X14, Rose Cr	25-Oct-07	333	0.000056
X14	X14, Rose Cr	29-Oct-07	263	<0.0002
X14	X14, Rose Cr	14-Nov-07	203	<0.0002
X14	X14, Rose Cr	21-Nov-07	212	0.000035
X14	X14, Rose Cr	10-Dec-07	246	<0.0002
X14	X14, Rose Cr	13-Dec-07	279	0.000042
X14	X14, Rose Cr	08-Jan-08	299	<0.0002
X14	X14, Rose Cr	24-Jan-08	364	0.00005
X14	X14, Rose Cr	19-Feb-08	406	<0.0002
X14	X14, Rose Cr	20-Feb-08	422	0.000062
X14	X14, Rose Cr	11-Mar-08	437	0.000061
X14	X14, Rose Cr	18-Mar-08	399	<0.0002
X14	X14, Rose Cr	14-Apr-08	619	<0.0002
X14	X14, Rose Cr	15-Apr-08	607	<0.0002
X14	X14, Rose Cr	22-Apr-08	613	<0.0002
X14	X14, Rose Cr	29-Apr-08	570	<0.0002
X14	X14, Rose Cr	29-Apr-08	563	0.000119
X14	X14, Rose Cr	06-May-08	343	<0.0002
X14	X14, Rose Cr	13-May-08	145	<0.0002
X14	X14, Rose Cr	15-May-08	160	<0.0002
X14	X14, Rose Cr	20-May-08	80	<0.0002
X14	X14, Rose Cr	22-May-08	80.4	0.000051
X14	X14, Rose Cr	26-May-08	72.4	0.000079
X14	X14, Rose Cr	26-May-08	55.3	0.000079
X14	X14, Rose Cr	27-May-08	52	<0.0002
X14	X14, Rose Cr	03-Jun-08	88	<0.0002
X14	X14, Rose Cr	10-Jun-08	103	<0.0002
X14	X14, Rose Cr	16-Jun-08	114	<0.0002
X14	X14, Rose Cr	17-Jun-08	102	<0.0002
X14	X14, Rose Cr	24-Jun-08	61	<0.0002
X14	X14, Rose Cr	24-Jun-08	65.4	0.00006
X14	X14, Rose Cr	01-Jul-08	143	<0.0002
X14	X14, Rose Cr	08-Jul-08	119	<0.0002
X14	X14, Rose Cr	14-Jul-08	104	<0.0002
X14	X14, Rose Cr	16-Jul-08	95	<0.0002
X14	X14, Rose Cr	22-Jul-08	128	<0.0002
X14	X14, Rose Cr	30-Jul-08	157	0.000029
X14	X14, Rose Cr	31-Jul-08	139	<0.0002
X14	X14, Rose Cr	05-Aug-08	178	<0.0002
X14	X14, Rose Cr	11-Aug-08	171	<0.0002
X14	X14, Rose Cr	12-Aug-08	172	<0.0002
X14	X14, Rose Cr	19-Aug-08	168	<0.0002
X14	X14, Rose Cr	28-Aug-08	116	<0.0002
X14	X14, Rose Cr	02-Sep-08	138	<0.0002
X14	X14, Rose Cr	09-Sep-08	116	<0.0002

Table A.2: Hardness and cadmium and data collected at Faro Stations, 2005 - 2008

X14	X14, Rose Cr	15-Sep-08	145	<0.0002
X14	X14, Rose Cr	16-Sep-08	138	<0.0002
X14	X14, Rose Cr	18-Sep-08	154	0.000029
X14	X14, Rose Cr	23-Sep-08	161	<0.0002
X14	X14, Rose Cr	30-Sep-08	160	<0.0002
X14	X14, Rose Cr	07-Oct-08	171	<0.0002
X14	X14, Rose Cr	07-Oct-08	160	0.000086
X14	X14, Rose Cr	14-Oct-08	204	<0.0002
X14	X14, Rose Cr	15-Oct-08	202	<0.0002
X14	X14, Rose Cr	21-Oct-08	220	<0.0002
X14	X14, Rose Cr	04-Nov-08	158	<0.0002
X14	X14, Rose Cr	01-Dec-08	236	<0.0002
X14	X14, Rose Cr	10-Dec-08	221	0.000036
X14	X14, Rose Cr	02-Feb-09	294	<0.0002
X14	X14, Rose Cr	25-Feb-09	421	0.000096
X14	X14, Rose Cr	3-Mar-09	364	0.000083
X14	X14, Rose Cr	27-Mar-09	368	0.000069
X14	X14, Rose Cr	2-Apr-09	709	0.00013
X14	X14, Rose Cr	8-Apr-09	716	0.00015
X14	X14, Rose Cr	16-Apr-09	728	0.00011
X14	X14, Rose Cr	23-Apr-09	729	0.0001
X14	X14, Rose Cr	29-Apr-09	757	0.00011
X14	X14, Rose Cr	7-May-09	73.6	0.000209
X14	X14, Rose Cr	14-May-09	193	0.000056
X14	X14, Rose Cr	21-May-09	98.4	0.000083
X14	X14, Rose Cr	31-May-09	78.8	0.000034
X14	X14, Rose Cr	7-Jun-09	60.8	0.000016
X14	X14, Rose Cr	8-Jun-09	63.9	0.000026
X14	X14, Rose Cr	14-Jun-09	125	0.00004
n			157	30
minimum			52	0.000016
maximum			812	0.0003
median			172	0.00006
mean			230.0	0.00009
standard deviation			170.4	0.00008
standard error			13.6	0.000014
# < detection limit			0	0
% <detection limit			0	0
# >criterion			-	25
% >criterion			-	83%
99th percentile			771	0.000300
95th percentile			639	0.000241
90th percentile			437	0.000185
water quality criterion			-	0.00003

Shaded values not included in summary statistics

Table A.2: Hardness and cadmium and data collected at Faro Stations, 2005 - 2008

Station	Name	Date	Hardness (mg/L)	Cadmium - total (mg/L)
P2	P2	27-Sep-07	153	0.00015
P2	P2	24-Oct-07	176	0.000204
P2	P2	22-Nov-07	214	0.000179
P2	P2	14-Dec-07	213	0.000179
P2	P2	24-Jan-08	217	0.000127
P2	P2	20-Feb-08	225	0.000128
P2	P2	12-Mar-08	218	0.000103
P2	P2	28-Apr-08	209	0.000097
P2	P2	21-May-08	95.1	0.000452
P2	P2	24-Jun-08	145	0.000505
P2	P2	29-Jul-08	143	0.000124
P2	P2	17-Sep-08	147	0.000209
P2	P2	08-Oct-08	146	0.000209
P2	P2	10-Dec-08	202	0.000171
P2	P2	24-Feb-09	221	0.000053
P2	P2	26-Mar-09	202	0.000111
P2	P2	20-May-09	118	0.000246
P2	P2	23-Jun-09	121	0.000226
n			18	18
minimum			95.1	0.000053
maximum			225	0.000505
median			189	0.000175
mean			175.8	0.00019
standard deviation			42.3	0.00012
standard error			10.0	0.00003
# < detection limit			0	0
% <detection limit			0	0
# >criterion			-	18
% >criterion			-	100%
99th percentile			224	0.0005
95th percentile			222	0.0005
90th percentile			219	0.0003
water quality criterion			-	0.00003

Shaded values not included in summary statistics

Table A.2: Hardness and cadmium and data collected at Faro Stations, 2005 - 2008

Station	Name	Date	Hardness (mg/L)	Cadmium - total (mg/L)
P4	P4	26-Sep-07	142	0.00009
P4	P4	24-Oct-07	173	0.000177
P4	P4	22-Nov-07	187	0.000099
P4	P4	14-Dec-07	209	0.000147
P4	P4	23-Jan-08	212	0.000118
P4	P4	20-Feb-08	214	0.000104
P4	P4	13-Mar-08	216	0.000094
P4	P4	28-Apr-08	200	0.000092
P4	P4	21-May-08	104	0.000634
P4	P4	24-Jun-08	117	0.000302
P4	P4	29-Jul-08	136	0.000074
P4	P4	17-Sep-08	136	0.00015
P4	P4	08-Oct-08	153	0.000165
P4	P4	10-Dec-08	200	0.000224
P4	P4	24-Feb-09	196	0.000033
P4	P4	26-Mar-09	199	0.000099
P4	P4	20-May-09	121	0.000212
P4	P4	23-Jun-09	126	0.000226
n			18	18
minimum			104	0.000033
maximum			216	0.000634
median			180	0.0001325
mean			168.9	0.00017
standard deviation			39.0	0.00013
standard error			9.2	0.00003
# < detection limit			0	0
% <detection limit			0	0
# >criterion			-	18
% >criterion			-	100%
99th percentile			216	0.0006
95th percentile			214	0.0004
90th percentile			213	0.0002
water quality criterion			-	0.00003

Shaded values not included in summary statistics

Table A.2: Hardness and cadmium and data collected at Faro Stations, 2005 - 2008

Station	Name	Date	Hardness (mg/L)	Cadmium - total (mg/L)
V27	V27	26-May-05	57	<0.0002
V27	V27	21-Sep-05	84	<0.0002
V27	V27	29-May-06	55	<0.0002
V27	V27	01-Aug-06	110	<0.0002
V27	V27	26-Sep-06	94	<0.0002
V27	V27	04-Jun-07	17	<0.0002
V27	V27	25-Jul-07	100	<0.0002
V27	V27	28-Aug-07		0.00005
V27	V27	26-Sep-07	92	0.00004
V27	V27	10-Oct-07	108	<0.0002
V27	V27	24-Oct-07	148	0.000081
V27	V27	22-Nov-07	201	0.000054
V27	V27	14-Dec-07	209	0.000054
V27	V27	23-Jan-08	241	0.000047
V27	V27	20-Feb-08	254	0.000047
V27	V27	13-Mar-08	286	0.000059
V27	V27	28-Apr-08	302	0.000073
V27	V27	21-May-08	90.7	0.000406
V27	V27	19-Jun-08	121	0.0003
V27	V27	24-Jun-08	76	0.000182
V27	V27	29-Jul-08	283	0.000439
V27	V27	19-Aug-08	323	<0.0002
V27	V27	23-Sep-08	116	<0.0002
V27	V27	10-Dec-08	326	0.000068
V27	V27	24-Feb-09	395	0.00008
n			24	15
minimum			17	0.00004
maximum			395	0.000439
median			118.5	0.000068
mean			170.4	0.00013
standard deviation			106.0	0.00014
standard error			21.6	0.00004
# < detection limit			0	0
% <detection limit			0	0
# >criterion			-	15
% >criterion			-	100%
99th percentile			379	0.00043
95th percentile			326	0.00042
90th percentile			317	0.00036
water quality criterion			-	0.00003

Shaded values not included in summary statistics

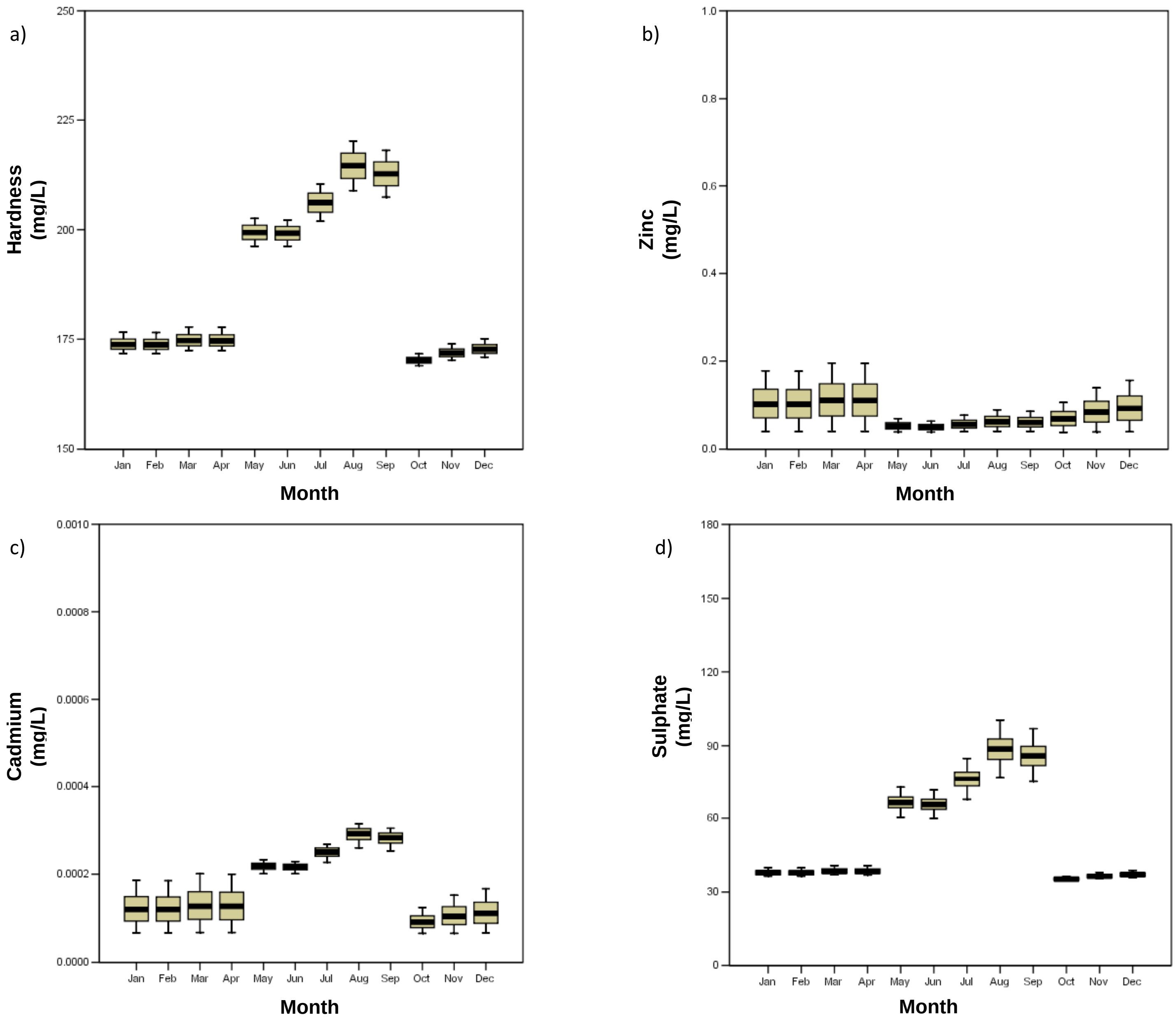

Figure A.1: Predicted monthly zinc, cadmium, sulphate and hardness concentrations at V27, 2027-2036. "Boxes" represent 25th and 75th percentiles with solid lines within boxes representing median values. "Whiskers represent minimum and maximum values. Data are presented at same scale as depicted in Figure 3.1.

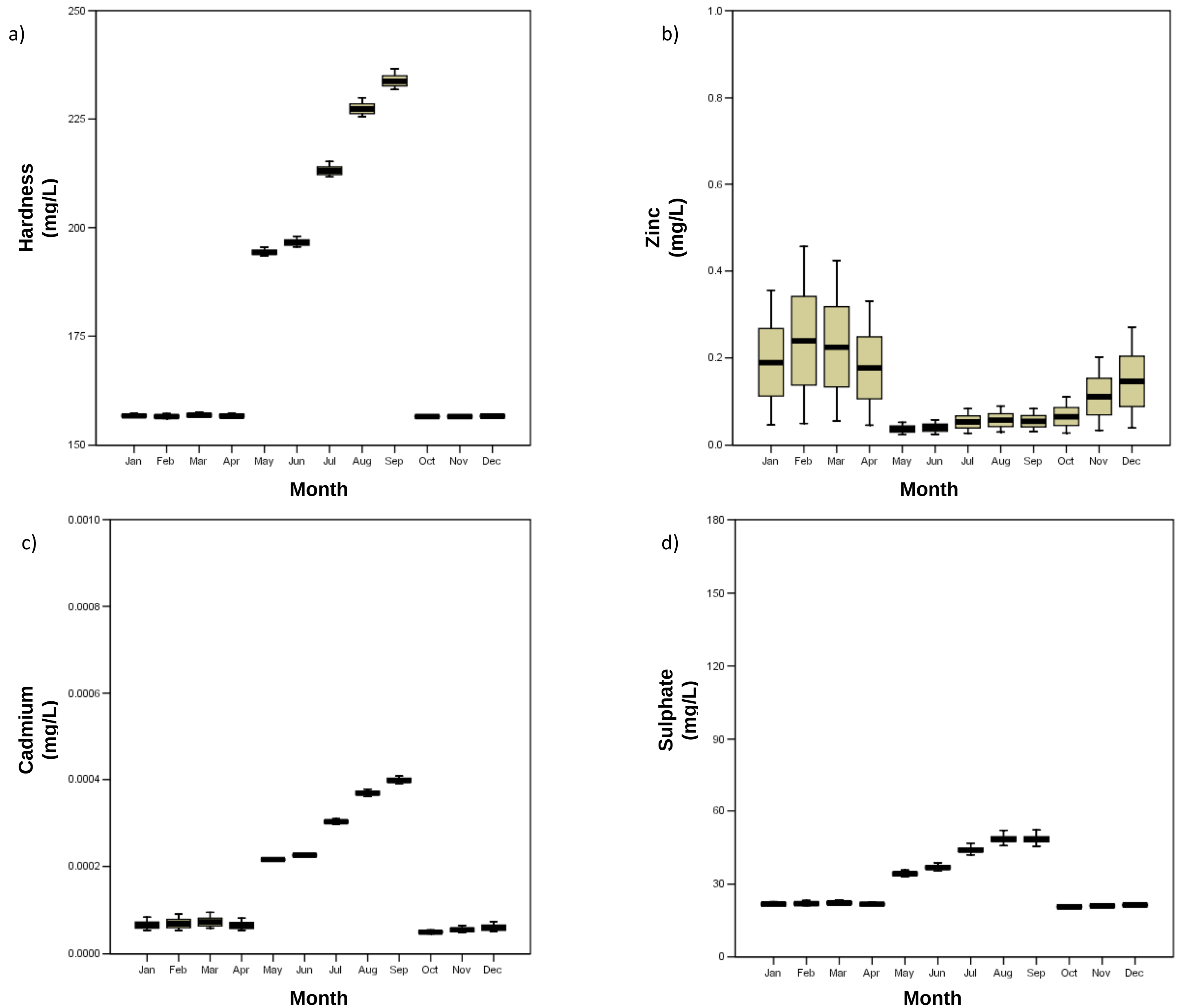

Figure A.2: Predicted monthly zinc, cadmium, sulphate and hardness concentrations at X14, 2027-2036. "Boxes" represent 25th and 75th percentiles with solid lines within boxes representing median values. "Whiskers" represent minimum and maximum values. Data are presented at same scale as depicted in Figure 3.2.

APPENDIX B

Zinc Toxicity Data

Table B.1: Summary of long-term effects of zinc on a variety of aquatic organisms

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [1]	pH	Authors	Year
Amphipod	*Hyalella azteca*	1 week	10 weeks	LOEC	Mortality	180	130	144	7.9-8.6	Borgmann et al	1993
Amphipod	*Hyalella azteca*	1 week	10 weeks	MATC	Mortality	134.16	130	107	7.9-8.6	Borgmann et al	1993
Amphipod	*Hyalella azteca*	1 week	10 weeks	NOEC	Mortality	100	130	80	7.9-8.6	Borgmann et al	1993
Amphipod	*Hyalella azteca*	1- 11 days	7 d	LC50	Mortality	56	18	239	6.44-8.68	Borgmann et al	2005
Amphipod	*Hyalella azteca*	1- 11 days	7 d	LC50	Mortality	70	18	299	6.44-8.68	Borgmann et al	2005
Amphipod	*Hyalella azteca*	1- 11 days	7 d	LC50	Mortality	222	124	185	7.23-8.98	Borgmann et al	2005
Atlantic salmon	*Salmo salar*	parr	14 d	LC50	Mortality	3640	351	1258	7.6	Hodson and Sprague	1975
Atlantic salmon	*Salmo salar*	parr	14 d	LC50	Mortality	5046	351	1744	7.6	Hodson and Sprague	1975
Atlantic salmon	*Salmo salar*	parr	14 d	LC50	Mortality	5198	351	1797	7.6	Hodson and Sprague	1975
Bluegill	*Lepomis macrochirus*	Not reported	20 d	TLM	Mortality	11300	370	3736	7.8 (7.7-8.0)	Pickering	1968
Brook Trout	*Salvelinus fontinalis*	Egg	100 weeks	EC10	Hatching success	418	45.9	808	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	24 w	IC10	egg fragility	200	45.9	386	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	8 weeks	LC10	Embryo (6 hours old) survival to hatch	1114	45.9	2153	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	12 weeks	LC10	Mortality	1215	45.9	2348	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	24 w	LOEC	egg fragility	266	45.9	514	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	100 weeks	LOEC	Hatching success	534	45.9	1032	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	12 weeks	LOEC	Mortality	1382	45.9	2671	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	12 weeks	LOEC	Mortality	2099	45.9	4056	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	8 weeks	LOEC	Mortality	1382	45.9	2671	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	24 w	MATC	egg fragility	174	45.9	336	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	8 weeks	MATC	Embryo (6 hours old) survival to hatch	990	45.9	1913	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	100 weeks	MATC	Hatching success	377	45.9	729	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	12 weeks	MATC	Mortality	990	45.9	1913	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	8 weeks	MATC	Mortality	1000	45.9	1932	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	8 weeks	MATC	Mortality	1685	45.9	3256	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	24 w	NOEC	egg fragility	114	45.9	220	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Egg	100 weeks	NOEC	Hatching success	266	45.9	514	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	12 weeks	NOEC	Mortality	709	45.9	1370	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	12 weeks	NOEC	Mortality	1353	45.9	2615	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	Embryo	8 weeks	NOEC	Mortality	724	45.9	1399	7.2-7.9	Holcombe et al.	1979
Brook Trout	*Salvelinus fontinalis*	30-45-d old fry	7 d	IC25	Growth	486.61		487		Lazorchak and Smith	2007
Brook Trout	*Salvelinus fontinalis*	30-45-d old fry	7 d	LC50	survival	798.91		799		Lazorchak and Smith	2007
Brook Trout	*Salvelinus fontinalis*	30-45-d old fry	7 d	LOEC	Growth	500		500		Lazorchak and Smith	2007
Brook Trout	*Salvelinus fontinalis*	30-45-d old fry	7 d	LOEC	survival	594.6		595		Lazorchak and Smith	2007
Brook Trout	*Salvelinus fontinalis*	30-45-d old fry	7 d	MATC	survival	443		443		Lazorchak and Smith	2007
Brook Trout	*Salvelinus fontinalis*	30-45-d old fry	7 d	NOEC	Growth	287.17		287		Lazorchak and Smith	2007
Brook Trout	*Salvelinus fontinalis*	30-45-d old fry	7 d	NOEC	survival	329.87		330		Lazorchak and Smith	2007
Brook Trout	*Salvelinus fontinalis*	Juvenile	14 d	LC10	Mortality	445		445	7.3	Nehring and Goettl	1974
Brook Trout	*Salvelinus fontinalis*	Juvenile	14 d	LC50	Mortality	960		960	7.3	Nehring and Goettl	1974
Bryozoan	*Lophopodella carteri*	2-3 days	96 h	LC50	Mortality	4093	205	2230	6.7-7.0	Pardue and Wood	1980
Bryozoan	*Lophopodella carteri*	2-3 days	96 h	LC50	Mortality	5630	205	3067	6.7-7.0	Pardue and Wood	1980
Bryozoan	*Pectinatella magnifica*	2-3 days	96 h	LC10	Mortality	2286	205	1245	6.7-7.0	Pardue and Wood	1980
Bryozoan	*Pectinatella magnifica*	2-3 days	96 h	LC50	Mortality	4310	205	2348	6.7-7.0	Pardue and Wood	1980
Bryozoan	*Plumatella emarginata*	2-3 days	96 h	LC10	Mortality	3474	205	1893	6.7-7.0	Pardue and Wood	1980
Bryozoan	*Plumatella emarginata*	2-3 days	96 h	LC50	Mortality	5300	205	2888	6.7-7.0	Pardue and Wood	1980
Chinook salmon	*Oncorhynchus tshawytscha*	Alevin	200 h	LC10	Mortality	364-661	23	1262-2292	7.1	Chapman	1978
Chinook salmon	*Oncorhynchus tshawytscha*	Fry	200 h	LC10	Mortality	68	23	236	7.1	Chapman	1978
Chinook salmon	*Oncorhynchus tshawytscha*	Fry	200 h	LC50	Mortality	97	23	336	7.1	Chapman	1978
Chironomid	*Chironomus riparius*	1st instar	11 weeks	LOEC	Development	100		100	7.3-7.7	Timmermans et al.	1992
Chironomid	*Tanytarsus dissimilis*	Larva	10 d	LC50	Mortality	36.8	46.8	70	7.3- 7.7	Anderson et al	1980
Common duckmeat	*Spirodela polyrrhiza*	Adult	4 d	IC50	Growth	935	ND	935		Gaur et al.	1994
crayfish	*Orconectes virilis*	Adult	14 d	LC10	Mortality	9920	26	31006	7.1	Mirenda	1986

Table B.1: Summary of long-term effects of zinc on a variety of aquatic organisms

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [1]	pH	Authors	Year
crayfish	*Orconectes virilis*	Adult	14 d	LC50	Mortality	84000	26	262550	7.1	Mirenda	1986
Cutthroat trout	*Oncorhynchus clarkii*	Juvenile	14 d	LC10	Mortality	453	40	983	7.2	Nehring and Goettl	1974
Cutthroat trout	*Oncorhynchus clarkii*	Juvenile	14 d	LC50	Mortality	670	40	1455	7.2	Nehring and Goettl	1974
Diatom	*Cyclotella meneghiniana*	Population	5 d	LC10	Growth rate	10689	121	9097	6.8	Cairns et al.	1978
Diatom	*Cyclotella meneghiniana*	Population	5 d	LC10	Growth rate	2803	121	2386	6.8	Cairns et al.	1978
Diatom	*Cyclotella meneghiniana*	Population	5 d	LC10	Growth rate	5716	121	4865	6.8	Cairns et al.	1978
Duckweed	*Lemna minor*	Adult	7 d	IC10	Growth	318		318	6.30-6.40	Dirilgen and Inel	1994
Duckweed	*Lemna minor*	Not reported	7 d	EC50	Growth	3014.48		3014	5.5 +/- 0.2	Drost et al	2007
Duckweed	*Lemna minor*	Not reported	7 d	EC10	Growth	1379.05		1379	6	Ince et al	1999
Duckweed	*Lemna minor*	Not reported	7 d	EC50	Growth	9600		9600	6	Ince et al	1999
Eurasian minnow	*Phoxinus phoxinus*	Yearling	150 d	LC10	Mortality	102	71	136	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Adult	30 d	LOEC	Growth	200	71	267	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Adult	150 d	LOEC	Growth	200	71	267	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Yearling	30 d	LOEC	Growth	130	71	174	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Yearling	150 d	LOEC	Growth	50	71	67	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Adult	30 d	MATC	Growth	161	71	215	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Adult	150 d	MATC	Growth	161	71	215	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Yearling	30 d	MATC	Growth	81	71	108	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Yearling	150 d	MATC	Growth	32	71	43	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Adult	30 d	NOEC	Growth	130	71	174	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Adult	150 d	NOEC	Growth	130	71	174	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Yearling	30 d	NOEC	Growth	50	71	67	7.1-8.2	Bengtsson	1974
Eurasian minnow	*Phoxinus phoxinus*	Yearling	150 d	NOEC	Growth	20	71	27	7.1-8.2	Bengtsson	1974
Fathead minnow	*Pimephales promelas*	Egg	NR	EC10	Eggs adhesiveness	46.9	46	90	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	LOEC/L	Eggs adhesiveness	145	46	280	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	LOEC/L	Hatching success	295	46	569	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	LOEC/L	Mortality	295	46	569	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	MATC	Eggs adhesiveness	106	46	204	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	MATC	Hatching success	207	46	399	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	MATC	Mortality	207	46	399	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	NOEC/L	Eggs adhesiveness	78	46	150	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	NOEC/L	Hatching success	145	46	280	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Egg	NR	NOEC/L	Mortality	145	46	280	7-8	Benoit and Holcombe	1978
Fathead minnow	*Pimephales promelas*	Larva	7 d	ChV	Growth	430	190	250	8.3-8.7	Magliette et al.	1995
Fathead minnow	*Pimephales promelas*	Larva	7 d	LC50	Mortality	780	190	453	8.3-8.7	Magliette et al.	1995
Fathead minnow	*Pimephales promelas*	Larva	7 d	LOEC/L	Growth	630	190	366	8.3-8.7	Magliette et al.	1995
Fathead minnow	*Pimephales promelas*	Larva	7 d	IC10	Growth	83.9	48	156		Norberg and Mount	1985
Fathead minnow	*Pimephales promelas*	Larva	7 d	LOEC	Growth	374	48	696		Norberg and Mount	1985
Fathead minnow	*Pimephales promelas*	Larva	7 d	LOEC	Mortality	184	48	342		Norberg and Mount	1985
Fathead minnow	*Pimephales promelas*	Larva	7 d	MATC	Growth	262	48	487		Norberg and Mount	1985
Fathead minnow	*Pimephales promelas*	Larva	7 d	MATC	Mortality	125	48	233		Norberg and Mount	1985
Fathead minnow	*Pimephales promelas*	Larva	7 d	NOEC	Growth	184	48	342		Norberg and Mount	1985
Fathead minnow	*Pimephales promelas*	Larva	7 d	NOEC	Mortality	84.6	48	157		Norberg and Mount	1985
Fathead minnow	*Pimephales promelas*	Larva	7 d	ChV	Growth	184	47	349	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	7 d	ChV	Growth	315	47	597	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	32 d	ChV	Mortality	188	47	356	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	7 d	LC50	Mortality	250	47	474	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	7 d	LC50	Mortality	283	47	536	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	7 d	LOEC	Growth	278	47	527	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	7 d	LOEC	Growth	454	47	860	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	32 d	LOEC	Mortality	275	47	521	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	7 d	NOEC	Growth	122	47	231	7.4-8.2	Norberg-King	1989

Table B.1: Summary of long-term effects of zinc on a variety of aquatic organisms

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [1]	pH	Authors	Year
Fathead minnow	*Pimephales promelas*	Larva	7 d	NOEC	Growth	218	47	413	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Larva	32 d	NOEC	Mortality	129	47	244	7.4-8.2	Norberg-King	1989
Fathead minnow	*Pimephales promelas*	Egg	12 d	NOEC	Mortality	1050	186	621	7.5-7.6	Pickering and Vigor	1965
Fathead minnow	*Pimephales promelas*	Fry	7 d	NOEC	Mortality	560	186	331	7.5-7.6	Pickering and Vigor	1965
Fathead minnow	*Pimephales promelas*	Egg	7 d	TLM	Mortality	1690	186	1000	7.5-7.6	Pickering and Vigor	1965
Fathead minnow	*Pimephales promelas*	Egg	12 d	TLM	Mortality	1630	186	964	7.5-7.6	Pickering and Vigor	1965
Fathead minnow	*Pimephales promelas*	Fry	7 d	TLM	Mortality	870	186	515	7.5-7.6	Pickering and Vigor	1965
Green alga	*Chlamydomonas sp.*	Population	10 d	LC10	Growth rate	8381	121	7133	6.8	Cairns et al.	1978
Green alga	*Chlamydomonas sp.*	Population	10 d	LC10	Growth rate	9398	121	7998	6.8	Cairns et al.	1978
Green alga	*Chlorella pyrenoidosa*	Not reported	24 h	EC50	Growth	57	25.51	181		Lin et al	2007
Green alga	*Chlorella pyrenoidosa*	Not reported	24 h	LOEC	Cell density	40	25.51	127		Lin et al	2007
Green alga	*Chlorella pyrenoidosa*	Not reported	24 h	MATC	Cell density	28.28	25.51	90		Lin et al	2007
Green alga	*Chlorella pyrenoidosa*	Not reported	24 h	NOEC	Cell density	20	25.51	64		Lin et al	2007
Green alga	*Chlorella vulgaris*	exponential growth phase	72 h	EC50	biomass	34		34		Muyssen and Janssen	2001
Green alga	*Chlorella vulgaris*	exponential growth phase	72 h	EC50	Growth	153		153		Muyssen and Janssen	2001
Green alga	*Pseudokirchneriella subcapitata*	Not reported	24 h	EC50	Growth	15		15		Chen et al	1997
Green alga	*Pseudokirchneriella subcapitata*	Not reported	96 h	EC50	Growth	178		178		Chen et al	1997
Green alga	*Pseudokirchneriella subcapitata*	Not reported	7 d	EC10	Growth	1.05		1.1	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	96 h	EC10	Growth	1.32		1.3	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	96 h	EC10	Growth	11.74		12	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	7 d	EC10	Growth	13.48		13	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	7 d	EC50	Growth	4.1		4.1	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	96 h	EC50	Growth	4.4		4.4	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	96 h	EC50	Growth	27		27	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Not reported	7 d	EC50	Growth	32		32	6.0-6.3	Chiaaudani and Vighi	1978
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	58.1	19.6	231	8	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	62.3	19.6	247	8	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	71.2	19.6	283	8	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	85	19.6	337	7	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	131	19.6	520	7	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	142	19.6	564	6	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	142	19.6	564	7	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	191	19.6	758	6	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	215	19.6	853	6	De Schamphelaere et al.	2004
Green alga	*Pseudokirchneriella subcapitata*	less than 72h	72 h	IC50	biomass	4.12	40	8.9	7.3	Errécalde et al.	1998
Green alga	*Pseudokirchneriella subcapitata*	less than 72h	72 h	IC50	biomass	32.7	40	71	7.3	Errécalde et al.	1998
Green alga	*Pseudokirchneriella subcapitata*	less than 72h	72 h	IC50	biomass	39.24	40	85	7.3	Errécalde et al.	1998
Green alga	*Pseudokirchneriella subcapitata*	less than 72h	72 h	IC50	Growth rate	11.12	40	24	7.3	Errécalde et al.	1998
Green alga	*Pseudokirchneriella subcapitata*	less than 72h	72 h	IC50	Growth rate	45.13	40	98	7.3	Errécalde et al.	1998
Green alga	*Pseudokirchneriella subcapitata*	less than 72h	72 h	IC50	Growth rate	68.68	40	149	7.3	Errécalde et al.	1998
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	10.5	24.4	35	7.8	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	15.8	24.4	52	7.7	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	21.1	24.4	70	7.65	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	26.4	24.4	87	7.3	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	26.4	24.4	87	7.4	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	29	24.4	96	7.6	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	47.5	24.4	157	7.1	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	94.8	24.4	313	6.8	Heijerick et al.	2002

Table B.1: Summary of long-term effects of zinc on a variety of aquatic organisms

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [1]	pH	Authors	Year
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	119	24.4	392	6.2	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	224	24.4	739	5.6	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	8.44	37.2	19	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	10.5	37.2	24	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	10.9	62.3	16	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	11.1	62.3	17	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	14.9	112.3	14	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	27.9	112.3	25	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	15.4	162.3	10	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	33.2	162.3	22	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	17.5	212.4	9	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	34.4	212.4	18	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	Population	72 h	EC50	biomass	54.9	262.6	24	7.5	Heijerick et al.	2002
Green alga	*Pseudokirchneriella subcapitata*	exponential growth phase	72 h	EC50	biomass	39		39		Muyssen and Janssen	2001
Green alga	*Pseudokirchneriella subcapitata*	exponential growth phase	72 h	EC50	Growth	138		138		Muyssen and Janssen	2001
Green alga	*Pseudokirchneriella subcapitata*	Not reported	48 h	EC50	Growth	96	130	77	7.8-8.8	Pardos et al	1998
Green alga	*Scenedesmus quadricauda*	Population	5 d	LC10	Growth rate	10451	121	8894	6.8	Cairns et al.	1978
Green alga	*Scenedesmus quadricauda*	Population	5 d	LC10	Growth rate	9559	121	8135	6.8	Cairns et al.	1978
Green alga	*Scenedesmus quadricauda*	Population	15 d	IC10	Growth	96.1		96	4.5	Starodub et al.	1987
Green alga	*Scenedesmus quadricauda*	Population	14 d	LOEC	Growth	225		225	6.5	Starodub et al.	1987
Green alga	*Scenedesmus quadricauda*	Population	14 d	LOEC	Growth	500		500	8.5	Starodub et al.	1987
Green alga	*Scenedesmus quadricauda*	Population	15 d	LOEC	Growth	100		100	4.5	Starodub et al.	1987
Green alga	*Scenedesmus quadricauda*	Population	14 d	MATC	Growth	150		150	6.5	Starodub et al.	1987
Green alga	*Scenedesmus quadricauda*	Population	14 d	MATC	Growth	335		335	8.5	Starodub et al.	1987
Green alga	*Scenedesmus quadricauda*	Population	14 d	NOEC	Growth	100		100	6.5	Starodub et al.	1987
Green alga	*Scenedesmus quadricauda*	Population	14 d	NOEC	Growth	225		225	8.5	Starodub et al.	1987
Green hydra	*Hydra viridissima*	Not reported	7 d	EC10	Population growth inhibition	52.23	20	204	7.25-7.53	Holdway et al	2001
Green hydra	*Hydra viridissima*	Not reported	7 d	LOEC	Population growth inhibition	75	20	293	7.25-7.53	Holdway et al	2001
Green hydra	*Hydra viridissima*	Not reported	7 d	MATC	Population growth inhibition	53.4	20	208	7.25-7.53	Holdway et al	2001
Green hydra	*Hydra viridissima*	Not reported	7 d	NOEC	Population growth inhibition	38	20	148	7.25-7.53	Holdway et al	2001
Mayfly	*Epeorus latifolium*	Larva	4 weeks	IC10	emergence	14.4	83	17	7.9-8.0	Hatakeyama	1989
Mayfly	*Epeorus latifolium*	Larva	4 weeks	LC10	Mortality	15	83	18	7.9-8.0	Hatakeyama	1989
Mayfly	*Rhithrogena hageni*	nymph	10 d	EC10	Mortality	2069.2	44.4	4113	7.77	Brinkman and Johnston	2008
Mayfly	*Rhithrogena hageni*	nymph	10 d	LOEC	Mortality	10800	44.4	21465	7.77	Brinkman and Johnston	2008
Mayfly	*Rhithrogena hageni*	nymph	10 d	MATC	Mortality	7565.71	44.4	15037	7.77	Brinkman and Johnston	2008
Mayfly	*Rhithrogena hageni*	nymph	10 d	NOEC	Mortality	5300	44.4	10534	7.77	Brinkman and Johnston	2008
Mixed invertebrates	N/A	Population	14 d	LOEC	Community similarity	17.1	135	13		Marshall et al.	1983
Mixed invertebrates	N/A	Population	14 d	LOEC	Primary productivity	17.1	135	13		Marshall et al.	1983
Mixed invertebrates	N/A	Population	14 d	LOEC	Specific zooplanton populations	17.1	135	13		Marshall et al.	1983
Mixed invertebrates	N/A	Population	14 d	LOEC	Zooplanction species diversity	17.1	135	13		Marshall et al.	1983
Mottled sculpin	*Cottus bairdi*	less than 2 months old	30 d	EC10	Mortality	155.7	154	108	7.5 (7.4-7.7)	Brinkman and Woodling	2005
Mottled sculpin	*Cottus bairdi*	less than 2 months old	30 d	LOEC	Mortality	379	154	263	7.5 (7.4-7.7)	Brinkman and Woodling	2005
Mottled sculpin	*Cottus bairdi*	less than 2 months old	30 d	MATC	Mortality	255	154	177	7.5 (7.4-7.7)	Brinkman and Woodling	2005
Mottled sculpin	*Cottus bairdi*	less than 2 months old	30 d	NOEC	Mortality	172	154	119	7.5 (7.4-7.7)	Brinkman and Woodling	2005
Mottled sculpin	*Cottus bairdi*	newly emerged	30 d	LC50	Mortality	32	48.6	59	7.38 (7.2-7.6)	Woodling et al	2002
Pink hydra	*Hydra vulgaris*	Not reported	7 d	EC10	Population growth inhibition	177.93	20	694	7.25-7.53	Holdway et al	2001
Pink hydra	*Hydra vulgaris*	Not reported	7 d	LOEC	Population growth inhibition	250	20	976	7.25-7.53	Holdway et al	2001
Rainbow trout	*Oncorhynchus mykiss*	Embryo	72 d	LC10	Mortality	458	25	1480	6.9-7.1	Cairns and Garton	1982
Rainbow trout	*Oncorhynchus mykiss*	Embryo	72 d	LOEC	Mortality	819	25	2646	6.9-7.1	Cairns and Garton	1982
Rainbow trout	*Oncorhynchus mykiss*	Embryo	72 d	MATC	Mortality	603	25	1948	6.9-7.1	Cairns and Garton	1982
Rainbow trout	*Oncorhynchus mykiss*	Embryo	72 d	NOEC	Mortality	444	25	1435	6.9-7.1	Cairns and Garton	1982
Rainbow trout	*Oncorhynchus mykiss*	Alevin	186 h	LC10	Mortality	256	23	888	7.1	Chapman	1978

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Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [1]	pH	Authors	Year
Rainbow trout	*Oncorhynchus mykiss*	Swim-up fry	200 h	LC10	Mortality	54	23	187	7.1	Chapman	1978
Rainbow trout	*Oncorhynchus mykiss*	Alevin	186 h	LC50	Mortality	555	23	1924	7.1	Chapman	1978
Rainbow trout	*Oncorhynchus mykiss*	Swim-up fry	200 h	LC50	Mortality	93	23	322	7.1	Chapman	1978
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	312	29.1	887	5.68	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	46.1	29.1	131	7.65	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	73.6	29.1	209	7.58	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	99.1	29.1	282	6.78	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	38.4	29.6	108	7.45	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	34.5	31.72	91	7.58-7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	171	104.99	164	7.58-7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	290	190.35	168	7.58-7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	337	398.68	105	7.58-7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	Growth	>1280	29.1	>3637	6.7	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	Growth	>1280	29.1	>3637	7.74	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	Growth	>1740	29.1	>4944	7.58	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	Growth	>800	29.1	>2273	5.68	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	Growth	345	29.1	980	7.61	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	Growth	>375	29.6	>1050	7.45	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	Growth	2310	29.6	6470	7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	survival	162	29.1	460	7.65	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	survival	166	29.1	472	7.61	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	survival	117	29.6	328	7.45	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LOEC	survival	2310	29.6	6470	7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	Growth	166	29.1	472	7.61	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	Growth	974	29.6	2728	7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	survival	45.4	29.1	129	7.73	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	survival	78.9	29.1	224	7.61	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	survival	31.5	29.6	88	7.45	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	survival	974	29.6	2728	7.87	De Schamphelaere and Janssen	2004
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	259	23.4	885	6.15	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	185	28.2	540	6.8	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	219	31.5	582	7.08	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	902	103.7	875	7.76	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC10	Mortality	578	176.3	358	8.13	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC50	Mortality	582	23.4	1989	6.15	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC50	Mortality	406	28.2	1185	6.8	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC50	Mortality	337	31.5	895	7.08	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC50	Mortality	1970	103.7	1910	7.76	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	LC50	Mortality	1850	176.3	1145	8.13	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	Mortality	370	23.4	1264	6.15	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	Mortality	324	28.2	945	6.8	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	Mortality	199	31.5	529	7.08	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	Mortality	771	103.7	748	7.76	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	30 d	NOEC	Mortality	696	176.3	431	8.13	De Schamphelaere et al.	2005
Rainbow trout	*Oncorhynchus mykiss*	15-25-d old fry	7 d	IC25	Growth	148.03		148		Lazorchak and Smith	2007
Rainbow trout	*Oncorhynchus mykiss*	15-25-d old fry	7 d	LC50	survival	195.38		195		Lazorchak and Smith	2007
Rainbow trout	*Oncorhynchus mykiss*	15-25-d old fry	7 d	LOEC	Growth	250		250		Lazorchak and Smith	2007
Rainbow trout	*Oncorhynchus mykiss*	15-25-d old fry	7 d	LOEC	survival	250		250		Lazorchak and Smith	2007
Rainbow trout	*Oncorhynchus mykiss*	15-25-d old fry	7 d	MATC	survival	177		177		Lazorchak and Smith	2007
Rainbow trout	*Oncorhynchus mykiss*	15-25-d old fry	7 d	NOEC	Growth	114.63		115		Lazorchak and Smith	2007
Rainbow trout	*Oncorhynchus mykiss*	15-25-d old fry	7 d	NOEC	survival	125		125		Lazorchak and Smith	2007
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	EC10	Length	300	19.7	1186	6.75 +/- 0.4	Mebane et al	2008

Table B.1: Summary of long-term effects of zinc on a variety of aquatic organisms

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [1]	pH	Authors	Year
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	EC10	Mortality	88	19.7	348	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	EC10	Weight	199	19.7	787	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	EC20	Mortality	147	19.7	581	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	EC20	Weight	387	19.7	1530	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	LOEC	Length	365	19.7	1443	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	LOEC	Mortality	117	19.7	462	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	LOEC	Weight	365	19.7	1443	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	MATC	Length	279	19.7	1103	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	MATC	Weight	279	19.7	1103	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	NOEC	Length	214	19.7	846	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Fry	69 days	NOEC	Weight	214	19.7	846	6.75 +/- 0.4	Mebane et al	2008
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	14 d	LC10	Mortality	318	37	737	7.3	Nehring and Goettl	1974
Rainbow trout	*Oncorhynchus mykiss*	Juvenile	14 d	LC50	Mortality	410	37	951	7.3	Nehring and Goettl	1974
Rainbow trout	*Oncorhynchus mykiss*	Fingerling	22 months	LOEC/L	Mortality	640	333	231	7.81	Sinley et al.	1974
Rainbow trout	*Oncorhynchus mykiss*	Fingerling	22 months	MATC	Mortality	453	333	164	7.81	Sinley et al.	1974
Rainbow trout	*Oncorhynchus mykiss*	Fingerling	22 months	NOEC/L	Mortality	320	333	116	7.81	Sinley et al.	1974
Rotifer	*Brachionus havanaensis*	adults and juveniles	18 d	EC10	Population growth inhibition	78.2		78	7.1-7.3	Juarez-Franco et al	2007
Rotifer	*Brachionus havanaensis*	adults and juveniles	18 d	LOEC	Population growth inhibition	141.94		142	7.1-7.3	Juarez-Franco et al	2007
Rotifer	*Brachionus havanaensis*	adults and juveniles	18 d	MATC	Population growth inhibition	100.36		100	7.1-7.3	Juarez-Franco et al	2007
Rotifer	*Brachionus havanaensis*	adults and juveniles	18 d	NOEC	Population growth inhibition	70.96		71	7.1-7.3	Juarez-Franco et al	2007
Sea trout	*Salmo trutta*	Juvenile	14 d	LC10	Mortality	504	39	1118	7.2	Nehring and Goettl	1974
Sea trout	*Salmo trutta*	Juvenile	14 d	LC50	Mortality	640	39	1420	7.2	Nehring and Goettl	1974
Snail	*Physa gyrina*	Adult	30 d	LC50	Mortality	771	36	1830	6.9	Nebeker et al.	1986
Snail	*Physa gyrina*	Adult	30 d	NOEC/L	Mortality	570	36	1353	6.9	Nebeker et al.	1986
Snail	*Potamopyrgus jenkinsi*	Juvenile	12 weeks	EC50	Growth	103	159	70	7.8-8.2	Dorgelo et al.	1995
Snail	*Potamopyrgus jenkinsi*	Juvenile	12 weeks	LOEC	Growth	115	159	78	7.8-8.2	Dorgelo et al.	1995
Snail	*Potamopyrgus jenkinsi*	Juvenile	12 weeks	MATC	Growth	91	159	61	7.8-8.2	Dorgelo et al.	1995
Snail	*Potamopyrgus jenkinsi*	Juvenile	12 weeks	NOEC	Growth	72	159	49	7.8-8.2	Dorgelo et al.	1995
Star duckweed	*Lemna trisulca*	Not reported	14 d	EC50	final yield (oven dry weight)	327	20.37	1256	7.8-8.3 +/- 0.3	Huebert and Shay	1992
Star duckweed	*Lemna trisulca*	Not reported	14 d	EC50	multiplication rate (number of fronds)	915.6	20.37	3518	7.8-8.3 +/- 0.3	Huebert and Shay	1992
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	LOEC	Reproduction - Number of young per adult	25	97.6	26	6	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	LOEC	Reproduction - Number of young per adult	25	97.6	26	8	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	LOEC	Reproduction - Number of young per adult	50	97.6	51	9	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	LOEC	Reproduction - Number of young per adult	100	113.6	90	6, 8, 9	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	LOEC	Reproduction - Number of young per adult	100	182	60	8	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	LOEC	Reproduction - Number of young per adult	50	182	30	6	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	MATC	Reproduction - Number of young per adult	35	97.6	36	9	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	MATC	Reproduction - Number of young per adult	71	113.6	64	6, 8, 9	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	MATC	Reproduction - Number of young per adult	71	182	43	8	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	NOEC	Reproduction - Number of young per adult	25	97.6	26	9	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	NOEC	Reproduction - Number of young per adult	50	113.6	45	6, 8, 9	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	NOEC	Reproduction - Number of young per adult	100	182	60	9	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	4 weeks	NOEC	Reproduction - Number of young per adult	50	182	30	8	Belanger et Cherry	1990
Water flea	*Ceriodaphnia dubia*	60-84 h	96 h	ChV	Mortality	70	169	45	7.8-8.2	Masters et al.	1991
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	7 d	ChV	Mortality	90	169	58	7.8-8.2	Masters et al.	1991
Water flea	*Ceriodaphnia dubia*	60-84 h	96 h	ChV	Reproduction - Brood size	45	169	29	7.8-8.2	Masters et al.	1991
Water flea	*Ceriodaphnia dubia*	Less than 24hrs	7 d	ChV	Reproduction - Brood size	105	169	67	7.8-8.2	Masters et al.	1991
Water flea	*Ceriodaphnia dubia*	Juvenile	9 d	EC50	Immobility	354	280	148	7.8	Muyssen and Janssen	2002
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC16	Repro - Number of young per survivor	70	49	128	7.4-8.2	Biesinger and Christensen	1972
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Repro - Number of young per survivor	102	49	187	7.4-8.2	Biesinger and Christensen	1972
Water flea	*Daphnia magna*	Less than 24hrs	21 d	LC50	Immobility	158	49	289	7.4-8.2	Biesinger and Christensen	1972
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC10	Reproduction - Number of young per adult	92.1	26.5	283	7.3	De Schamphelaere et al.	2005

Table B.1: Summary of long-term effects of zinc on a variety of aquatic organisms

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [1]	pH	Authors	Year
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC10	Reproduction - Number of young per adult	378	122.4	319	6.8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC10	Reproduction - Number of young per adult	59.2	124.7	49	8.4	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC10	Reproduction - Number of young per adult	265	183.2	159	8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC10	Reproduction - Number of young per adult	171	189.3	100	8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC10	Reproduction - Number of young per adult	126	196.4	71	8.2	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC10	Reproduction - Number of young per adult	196	250.5	90	7.2	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Reproduction - Number of young per adult	112	26.5	344	7.3	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Reproduction - Number of young per adult	536	122.4	452	6.8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Reproduction - Number of young per adult	171	124.7	142	8.4	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Reproduction - Number of young per adult	473	183	284	8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Reproduction - Number of young per adult	313	189	183	8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Reproduction - Number of young per adult	242	196.4	137	8.2	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	EC50	Reproduction - Number of young per adult	299	250.5	137	7.2	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	62.6	13.8	334	6	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	94.5	26.5	291	7.3	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	491	122.4	414	6.8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	72.7	124.7	60	8.4	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	251	183	151	8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	244	189.3	142	8	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	143	196.4	81	8.2	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Less than 24hrs	21 d	NOEC	Reproduction - Number of young per adult	155	250.5	71	7.2	De Schamphelaere et al.	2005
Water flea	*Daphnia magna*	Population	21 d	EC10	Population growth inhibition	420	225	211	8.1	Enserink et al.	1991
Water flea	*Daphnia magna*	Population	21 d	EC50	Population growth inhibition	570	225	287	8.1	Enserink et al.	1991
Water flea	*Daphnia magna*	Less than 24hrs	21 d	LC50	Mortality	840	225	423	8.1	Enserink et al.	1991
Water flea	*Daphnia magna*	Less than 24hrs	21 d	LOEC	Length	120	225	60	8.1	Enserink et al.	1991
Water flea	*Daphnia magna*	Less than 24hrs	21 d	LOEC	Mortality	1000	225	504	8.1	Enserink et al.	1991
Water flea	*Daphnia magna*	Less than 24hrs	21 d	LOEC	Repro - Number of young per survivor	1000	225	504	8.1	Enserink et al.	1991
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	328	35	797	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	233	110	215	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	277	110	256	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	313	110	289	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	557	110	514	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	179	240	85	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	308	240	147	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	331	240	158	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	394	240	188	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	502	240	239	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	634	240	302	8.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	911	240	434	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	423	240	202	6	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	114	370	38	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	341	370	113	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	600	370	198	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	EC10	Reproduction	90	370	30	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	445	35	1082	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	209	110	193	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	320	110	295	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	445	110	411	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	630	110	581	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	1000	240	477	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	209	240	100	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	320	240	153	7.25	Heijerick et al.	2003

Table B.1: Summary of long-term effects of zinc on a variety of aquatic organisms

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [1]	pH	Authors	Year
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	575	240	274	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	575	240	274	7.25	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	630	240	300	8.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	425	240	203	6	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	320	370	106	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	320	370	106	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	630	370	208	6.5	Heijerick et al.	2003
Water flea	*Daphnia magna*	Not reported	21 d	NOEC	Reproduction	630	370	208	8	Heijerick et al.	2003
Water flea	*Daphnia magna*	Adult	21 d	EC50	Reproduction	196	50	352	7	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	EC50	Reproduction	202	50	363	6.5	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	EC50	Reproduction	218	50	392	6	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	EC50	Reproduction	233	50	419	7.5	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	EC50	Reproduction	239	50	430	5.5	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	EC50	Reproduction	262	50	471	8	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	NOEC	Reproduction	117	50	210	8	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	NOEC	Reproduction	133	50	239	7.5	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	NOEC	Reproduction	154	50	277	7	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	NOEC	Reproduction	161	50	289	5.5	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	NOEC	Reproduction	162	50	291	6.5	Heijerick et al.	2005
Water flea	*Daphnia magna*	Adult	21 d	NOEC	Reproduction	168	50	302	6	Heijerick et al.	2005
Water flea	*Daphnia magna*	Less than 48h old	21 d	IC10	Reproduction - Number of young per adult	67.6	64.9	97	7.6-7.8	Münzinger and Monicelli	1991
Water flea	*Daphnia magna*	Less than 48h old	21 d	LOEC	Mortality	150	64.9	216	7.6-7.8	Münzinger and Monicelli	1991
Water flea	*Daphnia magna*	Less than 48h old	21 d	LOEC	Reproduction - Number of young per adult	150	64.9	216	7.6-7.8	Münzinger and Monicelli	1991
Water flea	*Daphnia magna*	Less than 48h old	21 d	MATC	Mortality	122	64.9	176	7.6-7.8	Münzinger and Monicelli	1991
Water flea	*Daphnia magna*	Less than 48h old	21 d	MATC	Reproduction - Number of young per adult	122	64.9	176	7.6-7.8	Münzinger and Monicelli	1991
Water flea	*Daphnia magna*	Less than 48h old	21 d	NOEC	Mortality	100	64.9	144	7.6-7.8	Münzinger and Monicelli	1991
Water flea	*Daphnia magna*	Less than 48h old	21 d	NOEC	Reproduction - Number of young per adult	100	64.9	144	7.6-7.8	Münzinger and Monicelli	1991
Water flea	*Daphnia magna*	Less than 24hrs	50 d	IC10	Reproduction - Brood size	29.8	51.9	52	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	IC10	Reproduction - Brood size	32.8	51.9	57	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	IC10	Reproduction - Brood size	55.7	51.9	97	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	IC10	Reproduction - Brood size	65.8	101.8	65	8.32	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	IC10	Reproduction - Brood size	158	197	89	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	IC10	Reproduction - Brood size	214	197	121	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Mortality	111.8	51.9	195	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Mortality	120.2	51.9	209	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Mortality	86.6	51.9	151	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Mortality	124.4	101.8	123	8.32	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Mortality	178.7	197	101	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Mortality	237.2	197	134	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Reproduction - Brood size	21.7	51.9	38	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Reproduction - Brood size	99.2	51.9	173	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Reproduction - Brood size	86.6	101.8	85	8.32	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Reproduction - Brood size	174.6	197	98	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	MATC	Reproduction - Brood size	224.7	197	127	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Mortality	112.5	51.9	196	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Mortality	120.8	51.9	210	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Mortality	87.5	51.9	152	8.39	Paulauskis and Winner	1988

Table B.1: Summary of long-term effects of zinc on a variety of aquatic organisms

Species Common Name	Scientific Name	Life Stage	Duration	Endpoint	Observed Effect	Effect Concentration (ug/L)	Test Hardness (mg/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [1]	pH	Authors	Year
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Mortality	125	101.8	123	8.32	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Mortality	179.2	197	101	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Mortality	237.5	197	134	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Reproduction - Brood size	100	51.9	174	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Reproduction - Brood size	25	51.9	44	8.39	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Reproduction - Brood size	87.5	101.8	86	8.32	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Reproduction - Brood size	175	197	99	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	50 d	NEC	Reproduction - Brood size	225	197	127	8.29	Paulauskis and Winner	1988
Water flea	*Daphnia magna*	Less than 24hrs	134 d	LOEC	Growth	100	145	73	8.2-9.5	Winner	1981
Water flea	*Daphnia magna*	Less than 24hrs	134 d	LOEC	Reproduction - Brood size	300	145	219	8.2-9.5	Winner	1981
zebra mussel	*Dreissena polymorpha*	Adult	10 weeks	EC50	Filtration rate	131	268	57	7.9	Kraak et al.	1994
zebra mussel	*Dreissena polymorpha*	Adult	10 weeks	LC10	Mortality	517	268	225	7.9	Kraak et al.	1994
zebra mussel	*Dreissena polymorpha*	Adult	10 weeks	LC50	Mortality	1065	268	463	7.9	Kraak et al.	1994
zebra mussel	*Dreissena polymorpha*	Adult	10 weeks	LOEC	Filtration rate	382	268	166	7.9	Kraak et al.	1994
zebra mussel	*Dreissena polymorpha*	Adult	10 weeks	MATC	Filtration rate	196	268	85	7.9	Kraak et al.	1994
zebra mussel	*Dreissena polymorpha*	Adult	10 weeks	NOEC	Filtration rate	101	268	44	7.9	Kraak et al.	1994

[1] If adjusted from another hardness, value was calculated using the following equation: EXP(LN(EFFECT conc)-(0.846)*(LN(measured water hardness)-LN(desired water hardness)))

(grey box) most sensitive effect end-point

Table B.2: Toxicity of zinc in samples collected at Faro Mine, Yukon

Species Tested	Test Type	Sample Identification	Date Collected	Date Tested	Original Sample IC25 (%)	Zn IC25 (mg/L)[a]	Hardness (mg/L)
Ceriodaphnia dubia	Samples spiked with zinc [b]	V1	27-Aug-04	13-Oct-04	Not tested	0.051	33
		V8	29-Apr-04	26-May-04	Not tested	0.075	305
		X10	27-Aug-04	13-Oct-04	Not tested	0.093	121
		X14	29-Apr-04	26-May-04	Not tested	0.005	485
	Samples with no zinc added [c]	R2	15-Jan-09	17-Jan-09	63	0.058	368
		R7	21-Aug-08	26-Aug-08	-[d]	>0.0016	80
		R7	15-Jan-09	17-Jan-09	>100	>0.0021	133
		X2	19-Aug-08	21-Aug-08	23	0.008	80
		X2	15-Jan-09	17-Jan-09	27	0.062	166
Oncorhynchus mykiss	Samples with no zinc added [c]	R2	15-Jan-09	20-Jan-09	>100	>0.0919	368
		R7	21-Aug-08	25-Aug-08	>100	>0.0016	80
		R7	15-Jan-09	20-Jan-09	>100	>0.0021	133
		X2	19-Aug-08	21-Aug-08	>100	>0.036	80
		X2	15-Jan-09	20-Jan-09	>100	>0.229	166
Pseudokerchneriella subcapitata	Samples spiked with zinc [b]	V8	29-Apr-04	13-May-04	Not tested	0.017	265
		V8	29-Apr-04	13-May-04	Not tested	0.017	265
		V8	1-Jun-04	10-Jun-04	Not tested	0.016	88
		V8	1-Jun-04	17-Jun-04	Not tested	0.025	88
		X14	29-Apr-04	13-May-04	Not tested	0.017	441
		X14	29-Apr-04	13-May-04	Not tested	0.015	441
		X14	1-Jun-04	10-Jun-04	Not tested	0.026	63
		X14	1-Jun-04	10-Jun-04	Not tested	0.021	63
		X14	1-Jun-04	17-Jun-04	Not tested	0.037	63
		X14	1-Jun-04	17-Jun-04	Not tested	0.034	63
	Samples with no zinc added [c]	R2	15-Jan-09	18-Jan-09	59	0.054	368
		R7	21-Aug-08	26-Aug-08	>95	>0.0015	80
		R7	15-Jan-09	18-Jan-09	>95	>0.0020	133
		X2	19-Aug-08	21-Aug-08	>95	>0.034	80
		X2	15-Jan-09	18-Jan-09	15	0.034	166

[a] For samples in which no zinc was added, the concentration shown is the zinc concentration present at the original sample IC25 (which equals the IC25 for zinc IF it can be assumed that zinc caused the sample toxicity.

[b] Testing managed by Gartner Lee Limited (now AECOM), Whitehorse, YT

[c] Detailed test results presented by Minnow (2009)

[d] Reproduction was slightly impaired in some sample dilutions but lack of dose response suggested a factor other than contaminant effects (e.g., possibly bacteria naturally present in the sample).

APPENDIX C

Cadmium Toxicity Data

Table C.1: Summary of long-term effects of cadmium on a variety of aquatic organisms

Species Common Name	Scientific Name	Life stage	Duration	Endpoint	Observed Effect	Test Hardness (mg/L)	Effect Concentration (ug/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [1]	pH	Authors	Year
Amphipod - gammarid	Echinogammarus meridionalis	Adult	6 d	LOEC/L	Feeding inhibition	263.4	6.35	2.4	7.92 (+-0.02)	Pestana et al.	2007
Amphipod - gammarid	Echinogammarus meridionalis	Adult	6 d	NOEC/L	Feeding inhibition	263.4	4.2	1.6	7.92 (+-0.02)	Pestana et al.	2007
Amphipod - gammarid	Gammarus pulex	Adult	5 d	LOEC/L	Behaviour - Inhibition of swimming ability	269.2	7.5	2.7	7.19 +- 0.02	Felten et al.	2007
Amphipod - gammarid	Gammarus pulex	Adult	7 d	LOEC/L	Behaviour - Inhibition of swimming ability	269.2	7.5	2.7	7.19 +- 0.02	Felten et al.	2007
Amphipod - gammarid	Gammarus pulex	Adult	7 d	LOEC/L	Feeding inhibition	269.2	15	5.4	7.19 +- 0.02	Felten et al.	2007
Amphipod - gammarid	Gammarus pulex	Adult	5 d	LOEC/L	Mortality	269.2	7.5	2.7	7.19 +- 0.02	Felten et al.	2007
Amphipod - gammarid	Gammarus pulex	Adult	7 d	LOEC/L	Mortality	269.2	15	5.4	7.19 +- 0.02	Felten et al.	2007
Amphipod - gammarid	Gammarus pulex	Adult	5 d	LOEC/L	Respiration	269.2	15	5.4	7.19 +- 0.02	Felten et al.	2007
Amphipod - gammarid	Gammarus pulex	Adult	7 d	LOEC/L	Respiration	269.2	7.5	2.7	7.19 +- 0.02	Felten et al.	2007
Amphipod - gammarid	Gammarus pulex	Adult	7 d	MATC	Feeding inhibition	269.2	10.6	3.8	7.19 +- 0.02	Felten et al.	2007
Amphipod - gammarid	Gammarus pulex	Adult	7 d	MATC	Mortality	269.2	10.6	3.8	7.19 +- 0.02	Felten et al.	2007
Amphipod - gammarid	Gammarus pulex	Adult	5 d	MATC	Respiration	269.2	10.6	3.8	7.19 +- 0.02	Felten et al.	2007
Amphipod - gammarid	Gammarus pulex	Adult	7 d	NOEC/L	Feeding inhibition	269.2	7.5	2.7	7.19 +- 0.02	Felten et al.	2007
Amphipod - gammarid	Gammarus pulex	Adult	7 d	NOEC/L	Mortality	269.2	7.5	2.7	7.19 +- 0.02	Felten et al.	2007
Amphipod - gammarid	Gammarus pulex	Adult	5 d	NOEC/L	Respiration	269.2	7.5	2.7	7.19 +- 0.02	Felten et al.	2007
Amphipod - scud	Hyalella azteca	7-8 d old	28 d	IC25	Biomass, decrease in	280	0.51	0.2	7.80	Ingersoll and Kemble	2001
Amphipod - scud	Hyalella azteca	7-8 d old	28 d	IC25	Length	280	2.6	0.9	7.80	Ingersoll and Kemble	2001
Amphipod - scud	Hyalella azteca	7-8 d old	42 d	IC25	Mortality	280	1.9	0.7	7.80	Ingersoll and Kemble	2001
Amphipod - scud	Hyalella azteca	7-8 d old	42 d	IC25	Reproduction	280	1.4	0.5	7.80	Ingersoll and Kemble	2001
Amphipod - scud	Hyalella azteca	7-8 d old	28 d	IC25	Weight	280	0.74	0.3	7.80	Ingersoll and Kemble	2001
Amphipod - scud	Hyalella azteca	7-8 d old	28 d	LOEC/L	Mortality	139.6	22.97	16.3	7.0 (0.3)	Stanley et al.	2005
Amphipod - scud	Hyalella azteca	7-8 d old	42 d	LOEC/L	Mortality	139.6	22.97	16.3	7.0 (0.3)	Stanley et al.	2005
Amphipod - scud	Hyalella azteca	7-8 d old	28 d	LOEC/L	Mortality	162.7	5.09	3.1	7.9 (0.1)	Stanley et al.	2005
Amphipod - scud	Hyalella azteca	7-8 d old	28 d	MATC	Mortality	139.6	12.52	8.9	7.0 (0.3)	Stanley et al.	2005
Amphipod - scud	Hyalella azteca	7-8 d old	42 d	MATC	Mortality	139.6	12.52	8.9	7.0 (0.3)	Stanley et al.	2005
Amphipod - scud	Hyalella azteca	7-8 d old	28 d	MATC	Mortality	162.7	3.56	2.2	7.9 (0.1)	Stanley et al.	2005
Amphipod - scud	Hyalella azteca	7-8 d old	28 d	NOEC/L	Mortality	139.6	6.82	4.8	7.0 (0.3)	Stanley et al.	2005
Amphipod - scud	Hyalella azteca	7-8 d old	42 d	NOEC/L	Mortality	139.6	6.82	4.8	7.0 (0.3)	Stanley et al.	2005
Amphipod - scud	Hyalella azteca	7-8 d old	28 d	NOEC/L	Mortality	162.7	2.49	1.5	7.9 (0.1)	Stanley et al.	2005
Amphipod - scud	Hyalella azteca	Juvenile	14 d	MATC	Mortality	17.0	0.16	1.0	5.5-7.7	Suedel et al	1997
Amphipod - scud	Hyalella azteca	Juvenile	7 d	MATC	Mortality	17.0	1.4	8.6	5.5-7.7	Suedel et al	1997
Amphipod - scud	Hyalella azteca	Juvenile	10 d	MATC	Mortality	17.0	1.4	8.6	5.5-7.7	Suedel et al	1997
Amphipod - scud	Hyalella azteca	Juvenile	14 d	NOEC/L	Growth	17.0	2	12.3	5.5-7.7	Suedel et al	1997
Atlantic salmon	Salmo salar	Egg	470 d	LOEC/L	Biomass, decrease in	28	2.5	9.2	7.3 (6.8-7.5)	Rombough and Garside	1982
Atlantic salmon	Salmo salar	Egg	470 d	LOEC/L	Weight	28	2.5	9.2	7.3 (6.8-7.5)	Rombough and Garside	1982
Atlantic salmon	Salmo salar	Egg	496 d	LOEC/L	Weight and Length	28	0.47	1.7	7.3 (6.8-7.5)	Rombough and Garside	1982
Atlantic salmon	Salmo salar	Egg	402 d	MATC	Biomass, decrease in	19	5.5	30.1	6.5 (6.3-6.8)	Rombough and Garside	1982
Atlantic salmon	Salmo salar	Egg	496 d	MATC	Biomass, decrease in	28	0.61	2.2	7.3 (6.8-7.5)	Rombough and Garside	1982
Atlantic salmon	Salmo salar	Early gastrulation	78 d	MATC	Hatching success	19	88	481	6.5 (6.3-6.8)	Rombough and Garside	1982
Atlantic salmon	Salmo salar	Eyed egg stage	45 d	MATC	Hatching success	19	156	853	6.5 (6.3-6.8)	Rombough and Garside	1982
Atlantic salmon	Salmo salar	Egg	96 d	MATC	Hatching success	19	156	853	6.5 (6.3-6.8)	Rombough and Garside	1982
Atlantic salmon	Salmo salar	Egg	45 d	MATC	Hatching success	28	490	1802	7.3 (6.8-7.5)	Rombough and Garside	1982
Atlantic salmon	Salmo salar	Egg	48 d	MATC	Hatching success	28	490	1802	7.3 (6.8-7.5)	Rombough and Garside	1982
Atlantic salmon	Salmo salar	Egg	158 d	MATC	Mortality after hatch	19	156	853	6.5 (6.3-6.8)	Rombough and Garside	1982
Atlantic salmon	Salmo salar	Egg	92 d	MATC	Mortality after hatch	28	4.5	16.5	7.3 (6.8-7.5)	Rombough and Garside	1982
Atlantic salmon	Salmo salar	Egg	92 d	MATC	Mortality after hatch	28	490	1802	7.3 (6.8-7.5)	Rombough and Garside	1982

Table C.1: Summary of long-term effects of cadmium on a variety of aquatic organisms

Species Common Name	Scientific Name	Life stage	Duration	Endpoint	Observed Effect	Test Hardness (mg/L)	Effect Concentration (ug/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [1]	pH	Authors	Year
Atlantic salmon	Salmo salar	Egg	402 d	MATC	Weight	19	5.5	30.1	6.5 (6.3-6.8)	Rombough and Garside	1982
Brook Trout	Salvelinus fontinalis	Larva	126 d	LOEC/L	Biomass, decrease in	45	3.8	8.6	7.6 (7.2-7.8)	Eaton et al.	1978
Brook Trout	Salvelinus fontinalis	Larva	126 d	MATC	Biomass, decrease in	45	2	4.5	7.6 (7.2-7.8)	Eaton et al.	1978
Brook Trout	Salvelinus fontinalis	Larva	126 d	NOEC/L	Biomass, decrease in	45	1.1	2.5	7.6 (7.2-7.8)	Eaton et al.	1978
Brown trout	Salmo trutta	Swim-up fry	30 d	IC20	Biomass, decrease in	29.2	0.87	3.1	7.54 (0.13)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Egg	55 d	IC20	Biomass, decrease in	30.6	2.22	7.5	7.72 (0.12)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Swim-up fry	30 d	IC20	Biomass, decrease in	67.6	2.18	3.3	7.60 (0.10)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Egg	55 d	IC20	Biomass, decrease in	71.3	4.71	6.7	7.75 (0.14)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Swim-up fry	30 d	IC20	Biomass, decrease in	151.0	6.62	4.3	7.51 (0.12)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Egg	55 d	IC20	Mortality	149.0	13.6	9.0	7.83 (0.14)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Swim-up fry	30 d	LOEC/L	Mortality	29.2	1.4	4.9	7.54 (0.13)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Egg	55 d	LOEC/L	Mortality	30.6	4.87	16.4	7.72 (0.12)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Swim-up fry	30 d	LOEC/L	Mortality	67.6	2.58	3.9	7.60 (0.10)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Egg	55 d	LOEC/L	Mortality	71.3	8.64	12.2	7.75 (0.14)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Egg	55 d	LOEC/L	Mortality	149.0	19.1	12.7	7.83 (0.14)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Swim-up fry	30 d	LOEC/L	Mortality	151.0	8.88	5.8	7.51 (0.12)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Swim-up fry	30 d	LOEC/L	Weight	29.2	2.72	9.6	7.54 (0.13)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Swim-up fry	30 d	LOEC/L	Weight	67.6	4.49	6.7	7.60 (0.10)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Swim-up fry	30 d	NOEC/L	Mortality	29.2	0.74	2.6	7.54 (0.13)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Egg	55 d	NOEC/L	Mortality	30.6	2.54	8.5	7.72 (0.12)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Swim-up fry	30 d	NOEC/L	Mortality	67.6	1.3	1.9	7.60 (0.10)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Egg	55 d	NOEC/L	Mortality	71.3	4.68	6.6	7.75 (0.14)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Egg	55 d	NOEC/L	Mortality	149.0	9.62	6.4	7.83 (0.14)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Swim-up fry	30 d	NOEC/L	Mortality	151.0	4.81	3.2	7.51 (0.12)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Swim-up fry	30 d	NOEC/L	Weight	29.2	1.4	4.9	7.54 (0.13)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Swim-up fry	30 d	NOEC/L	Weight	67.6	2.58	3.9	7.60 (0.10)	Brinkman and Hansen	2007
Brown trout	Salmo trutta	Embryo	83 d	LOEC/L	Biomass, decrease in	45	11.7	26.5	7.6 (7.2-7.8)	Eaton et al.	1978
Brown trout	Salmo trutta	Embryo	31 d	LOEC/L	Biomass, decrease in	45	11.2	25.4	7.6 (7.2-7.8)	Eaton et al.	1978
Brown trout	Salmo trutta	Larva	60 d	LOEC/L	Biomass, decrease in	45	11.7	26.5	7.6 (7.2-7.8)	Eaton et al.	1978
Brown trout	Salmo trutta	Larva	61 d	LOEC/L	Biomass, decrease in	45	3.7	8.4	7.6 (7.2-7.8)	Eaton et al.	1978
Brown trout	Salmo trutta	Larva	61 d	MATC	Biomass, decrease in	45	2	4.5	7.6 (7.2-7.8)	Eaton et al.	1978
Brown trout	Salmo trutta	Embryo	31 d	MATC	Biomass, decrease in	45	6.4	14.5	7.6 (7.2-7.8)	Eaton et al.	1978
Brown trout	Salmo trutta	Larva	60 d	MATC	Biomass, decrease in	45	6.7	15.2	7.6 (7.2-7.8)	Eaton et al.	1978
Brown trout	Salmo trutta	Embryo	83 d	MATC	Biomass, decrease in	45	6.7	15.2	7.6 (7.2-7.8)	Eaton et al.	1978
Brown trout	Salmo trutta	Larva	61 d	NOEC/L	Biomass, decrease in	45	1.1	2.5	7.6 (7.2-7.8)	Eaton et al.	1978
Brown trout	Salmo trutta	Embryo	31 d	NOEC/L	Biomass, decrease in	45	3.7	8.4	7.6 (7.2-7.8)	Eaton et al.	1978
Brown trout	Salmo trutta	Larva	60 d	NOEC/L	Biomass, decrease in	45	3.8	8.6	7.6 (7.2-7.8)	Eaton et al.	1978
Brown trout	Salmo trutta	Embryo	83 d	NOEC/L	Biomass, decrease in	45	3.8	8.6	7.6 (7.2-7.8)	Eaton et al.	1978
Bull trout	Salvelinus confluentus	Juvenile	55 d	LOEC/L	Growth	30.6	0.786	2.6	7.55 (SD = 0.12)	Hansen et al.	2002
Bull trout	Salvelinus confluentus	Juvenile	55 d	LOEC/L	Mortality	30.6	0.786	2.6	7.55 (SD = 0.12)	Hansen et al.	2002
Bull trout	Salvelinus confluentus	Juvenile	55 d	MATC	Growth	30.6	0.549	1.8	7.55 (SD = 0.12)	Hansen et al.	2002
Bull trout	Salvelinus confluentus	Juvenile	55 d	MATC	Mortality	30.6	0.549	1.8	7.55 (SD = 0.12)	Hansen et al.	2002
Bull trout	Salvelinus confluentus	Juvenile	55 d	NOEC/L	Growth	30.6	0.383	1.3	7.55 (SD = 0.12)	Hansen et al.	2002
Bull trout	Salvelinus confluentus	Juvenile	55 d	NOEC/L	Mortality	30.6	0.383	1.3	7.55 (SD = 0.12)	Hansen et al.	2002
Chinook salmon	Oncorhynchus tshawytscha	Swim-up fry	8 d	LC10	Mortality	23	1.2	5.4	7.1-7.5	Chapman	1978
Chinook salmon	Oncorhynchus tshawytscha	Alevin	8 d	LC10	Mortality	23	>6	>27	7.1-7.5	Chapman	1978

Table C.1: Summary of long-term effects of cadmium on a variety of aquatic organisms

Species Common Name	Scientific Name	Life stage	Duration	Endpoint	Observed Effect	Test Hardness (mg/L)	Effect Concentration (ug/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [1]	pH	Authors	Year
Cladocerans	Ceriodaphnia reticulata	Less than 24hrs	7 d	MATC	Reproduction - Number of young per adult	240	0.43	0.2	8.0 +- 0.3	Elnabarawy et al	1986
Cladocerans	Ceriodaphnia reticulata	Less than 24hrs	9 d	LOEC/L	Mortality	67.0	15.2	22.9	7.2-7.8	Spehar and Carlson	1984
Cladocerans	Ceriodaphnia reticulata	Less than 24hrs	9 d	LOEC/L	Reproduction	67.0	7.2	10.8	7.2-7.8	Spehar and Carlson	1984
Cladocerans	Ceriodaphnia reticulata	Less than 24hrs	9 d	MATC	Mortality	67.0	10.5	15.8	7.2-7.8	Spehar and Carlson	1984
Cladocerans	Ceriodaphnia reticulata	Less than 24hrs	9 d	MATC	Reproduction	67.0	4.9	7.4	7.2-7.8	Spehar and Carlson	1984
Cladocerans	Ceriodaphnia reticulata	Less than 24hrs	9 d	NOEC/L	Mortality	67.0	7.2	10.8	7.2-7.8	Spehar and Carlson	1984
Cladocerans	Ceriodaphnia reticulata	Less than 24hrs	9 d	NOEC/L	Reproduction	67.0	3.4	5.1	7.2-7.8	Spehar and Carlson	1984
Coho salmon	Oncorhynchus kisutch	Embryo	27 d	LOEC/L	Biomass, decrease in	45	3.4	8	7.6 (7.2-7.8)	Eaton et al.	1978
Coho salmon	Oncorhynchus kisutch	Embryo	47 d	LOEC/L	Biomass, decrease in	45	12.5	28	7.6 (7.2-7.8)	Eaton et al.	1978
Coho salmon	Oncorhynchus kisutch	Larva	62 d	LOEC/L	Biomass, decrease in	45	12.5	28	7.6 (7.2-7.8)	Eaton et al.	1978
Coho salmon	Oncorhynchus kisutch	Embryo	27 d	MATC	Biomass, decrease in	45	2.1	5	7.6 (7.2-7.8)	Eaton et al.	1978
Coho salmon	Oncorhynchus kisutch	Embryo	47 d	MATC	Biomass, decrease in	45	7.2	16	7.6 (7.2-7.8)	Eaton et al.	1978
Coho salmon	Oncorhynchus kisutch	Larva	62 d	MATC	Biomass, decrease in	45	7.2	16	7.6 (7.2-7.8)	Eaton et al.	1978
Coho salmon	Oncorhynchus kisutch	Embryo	27 d	NOEC/L	Biomass, decrease in	45	1.3	3	7.6 (7.2-7.8)	Eaton et al.	1978
Coho salmon	Oncorhynchus kisutch	Embryo	47 d	NOEC/L	Biomass, decrease in	45	4.1	9	7.6 (7.2-7.8)	Eaton et al.	1978
Coho salmon	Oncorhynchus kisutch	Larva	62 d	NOEC/L	Biomass, decrease in	45	4.1	9	7.6 (7.2-7.8)	Eaton et al.	1978
Duckweed	Lemna minor	Not reported	7 d	EC50	Growth rate	166.0	214	127	5.5 +- 0.2	Drost et al.	2007
Duckweed	Lemna minor	Not reported	6 d	EC50	Growth rate	166.0	214	127	5.5 +- 0.2	Drost et al.	2007
Duckweed	Lemna minor	Not reported	5 d	EC50	Growth rate	166.0	315	188	5.5 +- 0.2	Drost et al.	2007
Duckweed	Lemna minor	Not reported	3 d	EC50	Growth rate	166.0	393	234	5.5 +- 0.2	Drost et al.	2007
Duckweed	Lemna minor	Not reported	4 d	EC50	Growth rate	166.0	337	201	5.5 +- 0.2	Drost et al.	2007
European shrimp	Atyaephyra desmarestii	Adult	6 d	LOEC/L	Feeding inhibition	263.4	6.53	2.4	7.92 (+-0.02)	Pestana et al.	2007
European shrimp	Atyaephyra desmarestii	Adult	6 d	NOEC/L	Feeding inhibition	263.4	4.2	1.6	7.92 (+-0.02)	Pestana et al.	2007
Fathead minnow	Pimephales promelas	Juvenile	32 d	LOEC/L	Mortality	67.0	26.7	40.2	7.2-7.8	Spehar and Carlson	1984
Fathead minnow	Pimephales promelas	Juvenile	32 d	MATC	Mortality	67.0	18.9	28.5	7.2-7.8	Spehar and Carlson	1984
Fathead minnow	Pimephales promelas	Juvenile	32 d	NOEC/L	Mortality	67.0	13.4	20.2	7.2-7.8	Spehar and Carlson	1984
Fathead minnow	Pimephales promelas	Larva	10 d	MATC	Mortality	17.0	1.4	8.6	5.5-7.7	Suedel et al	1997
Fathead minnow	Pimephales promelas	Larva	7 d	MATC	Mortality	17.0	4.9	30.0	5.5-7.7	Suedel et al	1997
Fathead minnow	Pimephales promelas	Larva	14 d	MATC	Mortality	17.0	2.4	14.7	5.5-7.7	Suedel et al	1997
Fathead minnow	Pimephales promelas	Larva	10 d	NOEC/L	Growth	17.0	2	12.3	5.5-7.7	Suedel et al	1997
Fathead minnow	Pimephales promelas	Larva	14 d	NOEC/L	Growth	17.0	3	18.4	5.5-7.7	Suedel et al	1997
Great pond snail	Lymnaea stagnalis	Adult	4 weeks	EC50	Growth	284	142.2	48.9	6.65-8.14	Coeurdassier et al.	2003
Great pond snail	Lymnaea stagnalis	Adult	4 weeks	NOEC/L	Growth	284	80	27.5	6.65-8.14	Coeurdassier et al.	2003
Green alga	Ankistrodesmus falcatus	Population	96 h	NOEC/L	Growth	118.0	10	8	7.7 (7.2-8.2)	Baer et al.	1999
Green alga	Pseudokirchneriella subcapitata	Population	96 h	NOEC/L	Growth	118.0	5	4	7.7 (7.2-8.2)	Baer et al.	1999
Green alga	Pseudokirchneriella subcapitata	Population	72 h	EC50	Growth	250	43.5	17	8.1	Benhra et al.	1997
Green alga	Pseudokirchneriella subcapitata	Population	72 h	EC10	Growth rate	3.42	2.8	88	6.71	Kallqvist	2007
Green alga	Pseudokirchneriella subcapitata	Population	72 h	EC10	Growth rate	6.21	7.5	129	6.85	Kallqvist	2007
Green alga	Pseudokirchneriella subcapitata	Population	72 h	EC10	Growth rate	16.21	8.5	55	6.74	Kallqvist	2007
Green alga	Pseudokirchneriella subcapitata	Population	72 h	EC10	Growth rate	46.21	6	13	6.65	Kallqvist	2007
Green alga	Pseudokirchneriella subcapitata	Population	72 h	Mean EC10	Growth rate		5.7	53.6		Mean	
Green hydra	Hydra viridissima		7 d	NOEC/L	Population growth inhibition	19.5	0.4	2.1	7.25-7.53	Holdway et al.	2001
Lake Trout	Salvelinus namaycush	Embryo	41 d	LOEC/L	Biomass, decrease in	45	12.3	27.8	7.6 (7.2-7.8)	Eaton et al.	1978
Lake Trout	Salvelinus namaycush	Larva	64 d	LOEC/L	Biomass, decrease in	45	12.3	27.8	7.6 (7.2-7.8)	Eaton et al.	1978
Lake Trout	Salvelinus namaycush	Embryo	41 d	MATC	Biomass, decrease in	45	7.4	16.7	7.6 (7.2-7.8)	Eaton et al.	1978
Lake Trout	Salvelinus namaycush	Larva	64 d	MATC	Biomass, decrease in	45	7.4	16.7	7.6 (7.2-7.8)	Eaton et al.	1978

Table C.1: Summary of long-term effects of cadmium on a variety of aquatic organisms

Species Common Name	Scientific Name	Life stage	Duration	Endpoint	Observed Effect	Test Hardness (mg/L)	Effect Concentration (ug/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [1]	pH	Authors	Year
Lake Trout	Salvelinus namaycush	Embryo	41 d	NOEC/L	Biomass, decrease in	45	4.4	10.0	7.6 (7.2-7.8)	Eaton et al.	1978
Lake Trout	Salvelinus namaycush	Larva	64 d	NOEC/L	Biomass, decrease in	45	4.4	10.0	7.6 (7.2-7.8)	Eaton et al.	1978
Marsh snail	Lymnaea palustris	Adult	4 weeks	EC50	Growth	284	58.2	20.0	6.65-8.14	Coeurdassier et al.	2003
Marsh snail	Lymnaea palustris	Adult	4 weeks	EC50	Repro - No. egg masses per individual	284	60.9	20.9	6.65-8.14	Coeurdassier et al.	2003
Marsh snail	Lymnaea palustris	Adult	4 weeks	EC50	Repro - No. eggs per egg mass	284	124	42.6	6.65-8.14	Coeurdassier et al.	2003
Marsh snail	Lymnaea palustris	Adult	4 weeks	EC50	Repro - No. eggs per individual	284	64.7	22.2	6.65-8.14	Coeurdassier et al.	2003
Marsh snail	Lymnaea palustris	Adult	4 weeks	NOEC/L	Growth	284	40	13.8	6.65-8.14	Coeurdassier et al.	2003
Marsh snail	Lymnaea palustris	Adult	4 weeks	NOEC/L	Repro - No. egg masses per individual	284	40	13.8	6.65-8.14	Coeurdassier et al.	2003
Marsh snail	Lymnaea palustris	Adult	4 weeks	NOEC/L	Repro - No. eggs per individual	284	40	13.8	6.65-8.14	Coeurdassier et al.	2003
Midge	Chironomus riparius	1st instar	17 d	LOEC/L	Mortality	98.0	150	153.1	7.6	Pascoe et al.	1989
Midge	Chironomus riparius	1st instar	17 d	MATC	Mortality	98.0	47.4	48.4	7.6	Pascoe et al.	1989
Midge	Chironomus riparius	1st instar	17 d	NOEC/L	Mortality	98.0	15	15.3	7.6	Pascoe et al.	1989
Midge	Chironomus tentans	Less than 24hrs	20 d	IC25	Biomass, decrease in	280	10.3	3.6	7.80	Ingersoll and Kemble	2001
Midge	Chironomus tentans	Less than 24hrs	60 d	IC25	Hatching success	280	4	1.4	7.80	Ingersoll and Kemble	2001
Midge	Chironomus tentans	Less than 24hrs	20 d	IC25	Mortality	280	16.4	>5.7	7.80	Ingersoll and Kemble	2001
Midge	Chironomus tentans	Less than 24hrs	60 d	IC25	Percent emergence	280	8.1	2.8	7.80	Ingersoll and Kemble	2001
Midge	Chironomus tentans	Less than 24hrs	60 d	IC25	Repro - No. eggs per individual	280	>16.4	>5.7	7.80	Ingersoll and Kemble	2001
Midge	Chironomus tentans	Less than 24hrs	20 d	IC25	Weight	280	9.9	3.5	7.80	Ingersoll and Kemble	2001
Midge	Chironomus tentans	2nd instar	7 d	LOEC/L	Growth	17.0	500	3063.5	5.5-7.7	Suedel et al	1997
Midge	Chironomus tentans	2nd instar	10 d	LOEC/L	Growth	17.0	500	3063.5	5.5-7.7	Suedel et al	1997
Midge	Chironomus tentans	2nd instar	14 d	LOEC/L	Growth	17.0	100	612.7	5.5-7.7	Suedel et al	1997
Midge	Chironomus tentans	2nd instar	7 d	MATC	Mortality	17.0	707	4331.8	5.5-7.7	Suedel et al	1997
Midge	Chironomus tentans	2nd instar	10 d	MATC	Mortality	17.0	707	4331.8	5.5-7.7	Suedel et al	1997
Midge	Chironomus tentans	2nd instar	14 d	MATC	Mortality	17.0	707	4331.8	5.5-7.7	Suedel et al	1997
Mottled sculpin	Cottus bairdi	Swim-up fry	28 d	EC50	Biomass, decrease in	102	2.4	2	8.21	Besser et al.	2007
Mottled sculpin	Cottus bairdi	Swim-up fry	21 d	EC50	Biomass, decrease in	104	1.77	2	8.23	Besser et al.	2007
Northern pike	Esox lucius	Embryo	35 d	LOEC/L	Biomass, decrease in	45	12.9	29	7.6 (7.2-7.8)	Eaton et al.	1978
Northern pike	Esox lucius	Embryo	35 d	MATC	Biomass, decrease in	45	7.4	17	7.6 (7.2-7.8)	Eaton et al.	1978
Northern pike	Esox lucius	Embryo	35 d	NOEC/L	Biomass, decrease in	45	4.2	10	7.6 (7.2-7.8)	Eaton et al.	1978
Northwestern salamander	Ambystoma gracile	Larva	24 d	LOEC/L	Weight	45	193.1	437	6.8	Nebeker et al	1995
Northwestern salamander	Ambystoma gracile	Larva	10 d	LOEC/L	Weight	45	227.3	514	6.8	Nebeker et al	1995
Northwestern salamander	Ambystoma gracile	Larva	24 d	MATC	Weight	45	97.2	220	6.8	Nebeker et al	1995
Northwestern salamander	Ambystoma gracile	Larva	10 d	MATC	Weight	45	155.4	352	6.8	Nebeker et al	1995
Northwestern salamander	Ambystoma gracile	Larva	24 d	NOEC/L	Weight	45	48.9	111	6.8	Nebeker et al	1995
Northwestern salamander	Ambystoma gracile	Larva	10 d	NOEC/L	Weight	45	106.3	241	6.8	Nebeker et al	1995
Rainbow trout	Oncorhynchus mykiss	Adult	65 wks	LOEC/L	Reproduction - delay in oogenesis	250	1.77	0.7	7.4-8.0	Brown et al	1994
Rainbow trout	Oncorhynchus mykiss	Adult	65 wks	MATC	Reproduction - delay in oogenesis	250	0.91	0.4	7.4-8.0	Brown et al	1994
Rainbow trout	Oncorhynchus mykiss	Adult	65 wks	NOEC/L	Reproduction - delay in oogenesis	250	0.47	0.2	7.4-8.0	Brown et al	1994
Rainbow trout	Oncorhynchus mykiss	Alevin	8 d	LC10	Mortality	23	>6	>27	7.1-7.5	Chapman	1978
Rainbow trout	Oncorhynchus mykiss	Swim-up fry	8 d	LC10	Mortality	23	1	4.5	7.1-7.5	Chapman	1978
Rainbow trout	Oncorhynchus mykiss	Early life stage	62 d	EC10	Length	29.4	>2.5	>8.7	7.19 (SD = 0.30)	Mebane et al.	2007
Rainbow trout	Oncorhynchus mykiss	Early life stage	53 d	EC10	Mortality	19.7	0.82	4.3	6.75 (5.0-7.7)	Mebane et al.	2007
Rainbow trout	Oncorhynchus mykiss	Early life stage	62 d	EC10	Mortality	29.4	1.6	5.6	7.19 (SD = 0.30)	Mebane et al.	2007
Rainbow trout	Oncorhynchus mykiss	Early life stage	62 d	EC10	Weight	29.4	0.15	0.5	7.19 (SD = 0.30)	Mebane et al.	2007
Rainbow trout	Oncorhynchus mykiss	Early life stage	62 d	LOEC/L	Length	29.4	0.16	0.6	7.19 (SD = 0.30)	Mebane et al.	2007
Rainbow trout	Oncorhynchus mykiss	Early life stage	53 d	LOEC/L	Mortality	19.7	1.3	6.9	6.75 (5.0-7.7)	Mebane et al.	2007

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Species Common Name	Scientific Name	Life stage	Duration	Endpoint	Observed Effect	Test Hardness (mg/L)	Effect Concentration (ug/L)	Effect Concentration (ug/L) at 100 mg/L Hardness [1]	pH	Authors	Year
Rainbow trout	Oncorhynchus mykiss	Early life stage	62 d	LOEC/L	Mortality	29.4	2.5	8.7	7.19 (SD = 0.30)	Mebane et al.	2007
Rainbow trout	Oncorhynchus mykiss	Early life stage	62 d	LOEC/L	Weight	29.4	0.16	0.6	7.19 (SD = 0.30)	Mebane et al.	2007
Rainbow trout	Oncorhynchus mykiss	Early life stage	53 d	MATC	Mortality	19.7	0.88	4.6	6.75 (5.0-7.7)	Mebane et al.	2007
Rainbow trout	Oncorhynchus mykiss	Early life stage	62 d	MATC	Mortality	29.4	1.6	5.6	7.19 (SD = 0.30)	Mebane et al.	2007
Rainbow trout	Oncorhynchus mykiss	Early life stage	53 d	NOEC/L	Mortality	19.7	0.6	3.2	6.75 (5.0-7.7)	Mebane et al.	2007
Rainbow trout	Oncorhynchus mykiss	Early life stage	62 d	NOEC/L	Mortality	29.4	1	3.5	7.19 (SD = 0.30)	Mebane et al.	2007
Water flea	Ceriodaphnia dubia	Not reported	14 d	MATC	Mortality	17.0	11.4	69.8	5.5-7.7	Suedel et al	1997
Water flea	Ceriodaphnia dubia	Not reported	10 d	MATC	Mortality	17.0	11.4	69.8	5.5-7.7	Suedel et al	1997
Water flea	Ceriodaphnia dubia	Not reported	7 d	MATC	Mortality	17.0	11.4	69.8	5.5-7.7	Suedel et al	1997
Water flea	Ceriodaphnia dubia	Not reported	14 d	MATC	Reproduction	17.0	2	12.3	5.5-7.7	Suedel et al	1997
Water flea	Ceriodaphnia dubia	Not reported	10 d	MATC	Reproduction	17.0	2	12.3	5.5-7.7	Suedel et al	1997
Water flea	Ceriodaphnia dubia	Not reported	7 d	MATC	Reproduction	17.0	2	12.3	5.5-7.7	Suedel et al	1997
Water flea	Daphnia magna	Adult	7 d	EC10	Feeding inhibition	179	0.13	0.1	8.07 +- 0.07	Barata and Baird	2000
Water flea	Daphnia magna	Adult	7 d	EC10	Repro - brood mass	179	0.13	0.1	8.07 +- 0.07	Barata and Baird	2000
Water flea	Daphnia magna	Adult	7 d	EC10	Reproduction - Brood size	179	0.14	0.1	8.07 +- 0.07	Barata and Baird	2000
Water flea	Daphnia magna	Adult	7 d	EC10	Weight	179	1.65	0.9	8.07 +- 0.07	Barata and Baird	2000
Water flea	Daphnia magna	Adult	7 d	LC10	Mortality	179	1.15	0.6	8.07 +- 0.07	Barata and Baird	2000
Water flea	Daphnia magna	Less than 24hrs	21 d	EC16	Reproduction	45.3	0.17	0.4	7.74 (7.4-8.2)	Biesinger and Christensen	1972
Water flea	Daphnia magna	Not reported	21 d	LOEC/L	Reproduction - Number of young per adult	130	1.86	1.4		Borgmann et al	1989
Water flea	Daphnia magna	Not reported	21 d	MATC	Reproduction - Number of young per adult	130	0.64	0.5		Borgmann et al	1989
Water flea	Daphnia magna	Not reported	21 d	NOEC/L	Reproduction - Number of young per adult	130	0.22	0.2		Borgmann et al	1989
Water flea	Daphnia magna	Less than 24hrs	21 d	MATC	Repro - Number of young per survivor	53	1.52	2.9	7.5 +- 0.2	Chapman et al	1980
Water flea	Daphnia magna	Less than 24hrs	21 d	MATC	Repro - Number of young per survivor	103	0.21	0.2	7.9 +- 0.3	Chapman et al	1980
Water flea	Daphnia magna	Less than 24hrs	21 d	MATC	Reproduction - Number of young per adult	53	0.15	0.3	7.5 +- 0.2	Chapman et al	1980
Water flea	Daphnia magna	Less than 24hrs	21 d	MATC	Reproduction - Number of young per adult	103	0.38	0.4	7.9 +- 0.3	Chapman et al	1980
Water flea	Daphnia magna	Less than 24hrs	14 d	MATC	Reproduction - Number of young per adult	240	4.3	1.8	8.0 +- 0.3	Elnabarawy et al	1986
Water flea	Daphnia magna	24h	21 d	LOEC/L	Reproduction	249.8	1.94	0.8	8.0 +- 0.2	Kuhn et al	1989
Water flea	Daphnia magna	24h	21 d	MATC	Reproduction	249.8	1.09	0.4	8.0 +- 0.2	Kuhn et al	1989
Water flea	Daphnia magna	24h	21 d	NOEC/L	Reproduction	249.8	0.6	0.2	8.0 +- 0.2	Kuhn et al	1989
Water flea	Daphnia magna	Not reported	7 d	MATC	Mortality	78.0	7.1	9.2	6.9-8.3	Suedel et al	1997
Water flea	Daphnia magna	Not reported	10 d	MATC	Mortality	78.0	7.1	9.2	6.9-8.3	Suedel et al	1997
Water flea	Daphnia magna	Not reported	14 d	MATC	Mortality	78.0	7.1	9.2	6.9-8.3	Suedel et al	1997
Water flea	Daphnia magna	Neonate	7 d	MATC	Growth	90	1.2	1.3		Winner	1988
Water flea	Daphnia pulex	Less than 24hrs	14 d	MATC	Reproduction - Number of young per adult	240	13.7	5.6	8.0 +- 0.3	Elnabarawy et al	1986
White Sucker	Catostomus commersoni	Embryo	40 h	LOEC/L	Biomass, decrease in	45	12	27	7.6 (7.2-7.8)	Eaton et al.	1978
White Sucker	Catostomus commersoni	Embryo	40 h	MATC	Biomass, decrease in	45	7.1	16	7.6 (7.2-7.8)	Eaton et al.	1978
White Sucker	Catostomus commersoni	Embryo	40 h	NOEC/L	Biomass, decrease in	45	4.2	10	7.6 (7.2-7.8)	Eaton et al.	1978

[1] If adjusted from another hardness, value was calculated using the following equation: EXP(LN(EFFECT conc)-(1.023)*(LN(measured water hardness)-LN(desired water hardness)))

(shaded) most sensitive effect end-point for species

APPENDIX D

Sulphate Toxicity Data

Table D.1: Summary of short-term effects of sulphate in a variety of aquatic organisms. Shade indicates lowest species threshold or lowest effect concentration at test hardness at or near 100 mg/L.

Common Name	Scientific Name	Duration (days)	Sulphate Type	Endpoint	Effect	Hardness (mg/L)	Sulphate Ion Effect Conc (mg/L)	Sulphate Effect Concentration at 100 mg/L Hardness [1]	Presented by Singleton (2000)	Not Checked by Singleton	Data checked by Minnow	Used for Deriving Hardness Relationship (Table E.3)	Reference
amphipod	*Hyalella sp.*	4 days	Na2SO4	LC50	mortality	25	205		x			x	BC MELP 1996
amphipod	*Hyalella sp.*	4 days	Na2SO4	LC50	mortality	100	3711	3711	x			x	BC MELP 1996
amphipod	*Hyalella sp.*	4 days	Na2SO4	LC50	mortality	250	6787		x			x	BC MELP 1996
amphipod	*Hyalella azteca*	4 days	Na2SO4	LC50	mortality	100	1226	1226	x			x	BC Research
amphipod	*Hyallela azteca*	4 days	Na2SO4	LOEC	survival	100	3650	3650	x				BC Research
amphipod	*Hyallela azteca*	4 days	Na2SO4	NOEC	survival	100	1060	1060	x				BC Research
amphipod	*Hyalella azteca*	4 days	Na2SO4	LC50	mortality	25	491				x	x	Davies 2001
amphipod	*Hyalella azteca*	4 days	Na2SO4	LC50	mortality	30.5	453				x	x	Davies 2001
amphipod	*Hyalella azteca*	4 days	Na2SO4	LC50	mortality	50	1518				x	x	Davies 2001
amphipod	*Hyalella azteca*	4 days	Na2SO4	LC50	mortality	75	1700				x	x	Davies 2001
amphipod	*Hyalella azteca*	4 days	Na2SO4	LC50	mortality	123	2971	2524			x	x	Davies 2001
amphipod	*Hyalella azteca*	4 days	Na2SO4	LC50	mortality	257	4864				x	x	Davies 2001
amphipod	*Hyallela azteca*	4 days	Na2SO4	LC50	mortality	25	569				x	x	Davies and Hall 2007
amphipod	*Hyallela azteca*	4 days	Na2SO4	LC50	mortality	50	1448				x	x	Davies and Hall 2007
amphipod	*Hyallela azteca*	4 days	Na2SO4	LC50	mortality	75	1580				x	x	Davies and Hall 2007
amphipod	*Hyallela azteca*	4 days	Na2SO4	LC50	mortality	123	3144	2671			x	x	Davies and Hall 2007
amphipod	*Hyallela azteca*	4 days	Na2SO4	LC50	mortality	250	5259				x	x	Davies and Hall 2007
amphipod	*Hyalella azteca*	4 days	Na2SO4	LC50	mortality	25	491				x	x	Davies et al. 2003
amphipod	*Hyalella azteca*	4 days	Na2SO4	LC50	mortality	100	2971	2971			x	x	Davies et al. 2003
amphipod	*Hyalella azteca*	4 days	Na2SO4	LC50	mortality	250	4864				x	x	Davies et al. 2003
amphipod	not given	1 day	Na2SO4	LC50	mortality	-	1609		x		x		Dowden and Bennett 1965
amphipod	not given	2 days	Na2SO4	LC50	mortality	-	750		x		x		Dowden and Bennett 1965
amphipod	not given	3 days	Na2SO4	LC50	mortality	-	595		x		x		Dowden and Bennett 1965
amphipod	not given	4 days	Na2SO4	LC50	mortality	-	595	595	x		x		Dowden and Bennett 1965
amphipod	*Hyalella azteca*	4 days	Na2SO4	LC10	mortality	94	262	275			x		Soucek and Kennedy 2005
bluegill	*Lepomis macrochirus*	1 day	MgSO4	LC50	mortality	-	15162		x		x		Dowden and Bennett 1965
bluegill	*Lepomis macrochirus*	1 day	CaSO4	LC50	mortality	-	2102	2102	x	x	x		Patrick et al. 1968
bluegill	*Lepomis macrochirus*	4 days	Na2SO4	LC50	mortality	44.23	9130	17364	x [a]	x	x		Trama 1954
chironomid	not given	4 days	Na2SO4	LC50	mortality	25	6667		x				BC MELP 1996
chironomid	not given	4 days	Na2SO4	LC50	mortality	100	5868	5868	x				BC MELP 1996
chironomid	not given	4 days	Na2SO4	LC50	mortality	250	4173		x				BC MELP 1996
coho salmon	*Oncorhynchus kisutch*	4 days	Na2SO4	LC50	mortality	25	5742		x			x	BC MELP 1996
coho salmon	*Oncorhynchus kisutch*	4 days	Na2SO4	LC50	mortality	100	9550	9550	x			x	BC MELP 1996
coho salmon	*Oncorhynchus kisutch*	4 days	Na2SO4	LC50	mortality	250	9875		x			x	BC MELP 1996
fingernail clam	*Sphaerium simile*	4 days	Na2SO4	LC10	mortality	94	1502	1577			x		Soucek and Kennedy 2005
minnow, carp	*Cyprinidae*	1 day	Na2SO4		mortality	-	3042	3042	x	x			Turoboyski 1960
mosquito	*Culex sp*	1 day	Na2SO4	LC50	mortality	-	7727	7727	x		x		Dowden and Bennett 1965
mosquito	*Culex sp*	2 days	Na2SO4	LC50	mortality	-	9025		x		x		Dowden and Bennett 1965
pond snail	*Lymnaea sp*	1 day	Na2SO4	EC50	hatching	-	3651		x				Dowden and Bennett 1965
pond snail	*Lymnaea sp*	2 days	Na2SO4	EC50	hatching	-	3651		x				Dowden and Bennett 1965
pond snail	*Lymnaea sp*	3 days	Na2SO4	EC50	hatching	-	3651		x				Dowden and Bennett 1965
pond snail	*Lymnaea sp*	4 days	Na2SO4	EC50	hatching	-	2402	2402	x				Dowden and Bennett 1965
pond snail	*Lymnaea sp*	1 day	MgSO4	EC50	hatching	-	8403		x		x		Dowden and Bennett 1965
pond snail	*Lymnaea sp*	2 days	MgSO4	EC50	hatching	-	5207		x		x		Dowden and Bennett 1965
pond snail	*Lymnaea sp*	2 days	MgSO4	EC50	hatching	-	5027		x		x		Dowden and Bennett 1965
pond snail	*Lymnaea sp*	2 days	MgSO4	EC50	hatching	-	4988		x		x		Dowden and Bennett 1965
rainbow trout	*Oncorhynchus mykiss*	4 days	Na2SO4	LC50	mortality	25	5000		x			x	BC MELP 1996
rainbow trout	*Oncorhynchus mykiss*	4 days	Na2SO4	LC50	mortality	100	9750	9750	x			x	BC MELP 1996
rainbow trout	*Oncorhynchus mykiss*	4 days	Na2SO4	LC50	mortality	250	9900		x			x	BC MELP 1996
Sailfin molly	*Poecillia latipinna*	1 day	Na2SO4	LC50	mortality	-	13548		x	x	x		Dowden and Bennett 1965
Sailfin molly	*Poecillia latipinna*	2 days	Na2SO4	LC50	mortality	-	10814	10814	x		x		Dowden and Bennett 1965

Table D.1: Summary of short-term effects of sulphate in a variety of aquatic organisms. Shade indicates lowest species threshold or lowest effect concentration at test hardness at or near 100 mg/L.

Common Name	Scientific Name	Duration (days)	Sulphate Type	Endpoint	Effect	Hardness (mg/L)	Sulphate Ion Effect Conc (mg/L)	Sulphate Effect Concentration at 100 mg/L Hardness [1]	Presented by Singleton (2000)	Not Checked by Singleton	Data checked by Minnow	Used for Deriving Hardness Relationship (Table E.3)	Reference
striped bass larvae	*Morone saxatilis*	1 day	Na2SO4	LC50	mortality	-	2000		x		x		Hughes 1973
striped bass larvae	*Morone saxatilis*	2 days	Na2SO4	LC50	mortality	-	1000		x		x		Hughes 1973
striped bass larvae	*Morone saxatilis*	3 days	Na2SO4	LC50	mortality	-	500		x		x		Hughes 1973
striped bass larvae	*Morone saxatilis*	4 days	Na2SO4	LC50	mortality	-	250	250	x		x		Hughes 1973
striped bass fingerlings	*Morone saxatilis*	1 day	Na2SO4	LC50	mortality	-	3500		x		x		Hughes 1973
striped bass fingerlings	*Morone saxatilis*	2 days	Na2SO4	LC50	mortality	-	3500		x		x		Hughes 1973
striped bass fingerlings	*Morone saxatilis*	3 days	Na2SO4	LC50	mortality	-	3500		x		x		Hughes 1973
striped bass fingerlings	*Morone saxatilis*	4 days	Na2SO4	LC50	mortality	-	3500		x		x		Hughes 1973
water flea	*Ceriodaphnia dubia*	2 days	Na2SO4	LC10	mortality	89	1759	1928			x		Soucek and Kennedy 2005
water flea	*Ceriodaphnia dubia*	2 days	Na2SO4	LC10	mortality	194	2173				x		Soucek and Kennedy 2005
water flea	*Ceriodaphnia dubia*	2 days	Na2SO4	LC10	mortality	288	2389				x		Soucek and Kennedy 2005
water flea	*Ceriodaphnia dubia*	2 days	Na2SO4	LC10	mortality	390	2744				x		Soucek and Kennedy 2005
water flea	*Ceriodaphnia dubia*	2 days	Na2SO4	LC10	mortality	484	2793				x		Soucek and Kennedy 2005
water flea	*Ceriodaphnia dubia*	2 days	Na2SO4	LC10	mortality	578	2547				x		Soucek and Kennedy 2005
water flea	*Ceriodaphnia dubia*	2 days	Na2SO4	LC50	mortality	89	2050				x	x	Soucek and Kennedy 2005
water flea	*Ceriodaphnia dubia*	2 days	Na2SO4	LC50	mortality	194	3000				x	x	Soucek and Kennedy 2005
water flea	*Ceriodaphnia dubia*	2 days	Na2SO4	LC50	mortality	288	2946				x	x	Soucek and Kennedy 2005
water flea	*Ceriodaphnia dubia*	2 days	Na2SO4	LC50	mortality	390	3174				x	x	Soucek and Kennedy 2005
water flea	*Ceriodaphnia dubia*	2 days	Na2SO4	LC50	mortality	484	3516				x	x	Soucek and Kennedy 2005
water flea	*Ceriodaphnia dubia*	2 days	Na2SO4	LC50	mortality	578	3288				x	x	Soucek and Kennedy 2005
water flea	*Daphnia magna*	2 days	Na2SO4	LETC	immobility	-	4029		x	x			Anderson 1944
water flea	*Daphnia magna*	0.01 days	Na2SO4		locomotion	-	1556		x	x			Anderson 1944
water flea	*Daphnia magna*	0.01 days	Na2SO4		locomotion	-	1082	1082	x	x			Anderson 1944
water flea	*Daphnia magna*	2 days	Na2SO4	LC50	mortality	-	9124	9124	x	x			Arambasic et al. 1995
water flea	*Daphnia magna*	2 days	Na2SO4	LC50	mortality	25	537		x			x	BC MELP 1996
water flea	*Daphnia magna*	2 days	Na2SO4	LC50	mortality	100	6281	6281	x			x	BC MELP 1996
water flea	*Daphnia magna*	2 days	Na2SO4	LC50	mortality	250	7442		x			x	BC MELP 1996
water flea	*Daphnia magna*	2 days	Na2SO4	LC50	mortality	100	5218	5218	x			x	BC Research
water flea	*Daphnia magna*	2 days	Na2SO4	LOEC		100	7460		x				BC Research
water flea	*Daphnia magna*	2 days	Na2SO4	NOEC		100	3650		x				BC Research
water flea	*Daphnia magna*	2 days	Na2SO4	LC50	mortality	25	1194				x	x	Davies and Hall 2007
water flea	*Daphnia magna*	2 days	Na2SO4	LC50	mortality	50	1551				x	x	Davies and Hall 2007
water flea	*Daphnia magna*	2 days	Na2SO4	LC50	mortality	75	3342				x	x	Davies and Hall 2007
water flea	*Daphnia magna*	2 days	Na2SO4	LC50	mortality	100	3203	3203			x	x	Davies and Hall 2007
water flea	*Daphnia magna*	2 days	Na2SO4	LC50	mortality	25	957				x	x	Davies et al. 2003
water flea	*Daphnia magna*	2 days	Na2SO4	LC50	mortality	50	1768				x	x	Davies et al. 2003
water flea	*Daphnia magna*	2 days	Na2SO4	LC50	mortality	75	3155	3958			x	x	Davies et al. 2003
water flea	*Daphnia magna*	1 day	Na2SO4	LC50	mortality	-	5670		x		x		Dowden and Bennett 1965
water flea	*Daphnia magna*	2 days	Na2SO4	LC50	mortality	-	1058		x		x		Dowden and Bennett 1965
water flea	*Daphnia magna*	3 days	Na2SO4	LC50	mortality	-	490		x		x		Dowden and Bennett 1965
water flea	*Daphnia magna*	4 days	Na2SO4	LC50	mortality	-	426	426	x		x		Dowden and Bennett 1965
water flea	*Daphnia magna*	4 days	Na2SO4	LC50	mortality	-	3075		x		x		Dowden and Bennett 1965
water flea	*Daphnia magna*	1 day	Na2SO4	LC50	mortality	-	4599		x		x		Dowden and Bennett 1965
water flea	*Daphnia magna*	2 days	Na2SO4	LC50	mortality	-	4125		x		x		Dowden and Bennett 1965
water flea	*Daphnia magna*	1 day	MgSO4	LC50	mortality	-	768		x		x		Dowden and Bennett 1965
water flea	*Daphnia magna*	2 days	MgSO4	LC50	mortality	-	765		x		x		Dowden and Bennett 1965
water flea	*Daphnia magna*	3 days	MgSO4	LC50	mortality	-	687		x		x		Dowden and Bennett 1965
water flea	*Daphnia magna*	4 days	MgSO4	LC50	mortality	-	629		x		x		Dowden and Bennett 1965
water flea	*Daphnia magna*	4 days	MgSO4	LC50	mortality	-	3035		x		x		Dowden and Bennett 1965
water flea	*Daphnia magna*	4.2 days	Na2SO4	EC50	IMM	-	3074		x	x			Freeman and Fowler 1953

[1] If adjusted from another hardness, value was calculated using the following equation: EXP(LN(EFFECT conc)-(0.788)*(LN(measured water hardness)-LN(desired water hardness)))

Note: 0.788 is the short-term slope for all species combined

(shaded) Lowest short-term threshold toxicity value for species

Table D.2: Summary of long-term effects of sulphate in a variety of aquatic organisms. Shade indicates lowest species threshold or lowest effect concentration at test hardness at or near 100 mg/L.

Common Name	Scientific Name	Duration (days)	Sulphate Type	Endpoint	Effect	Hardness (mg/L)	Sulphate Ion Effect Conc (mg/L)	Sulphate Effect Concentration at 100 mg/L hardness[1]	Presented by Singleton (2000)	Not Checked by Singleton	Data checked by Minnow	Used for Deriving Hardness Relationship (Table E.3)	Reference
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	LOEC	Chl a b mg	19	400				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	LOEC	shoot length	19	400				x	x	Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	LOEC	shoot dry wt	105	400				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	LOEC	shoot dry wt	19	600				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	LOEC	Chl a b mg	26	600				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	LOEC	shoot length	26	800				x	x	Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	LOEC	Chl a b mg	105	1000				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	LOEC	shoot dry wt	26	1500				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	LOEC	shoot length	105	1500				x	x	Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	MATC	Chl a b mg	19	283				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	MATC	shoot length	19	283				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	MATC	shoot dry wt	105	283	272			x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	MATC	shoot dry wt	19	490				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	MATC	Chl a b mg	26	490				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	MATC	shoot length	26	693				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	MATC	Chl a b mg	105	894				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	MATC	shoot dry wt	26	1225				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	MATC	shoot length	105	1225				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	NOEC	Chl a b mg	19	200				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	NOEC	shoot length	19	200				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	NOEC	shoot dry wt	105	200				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	NOEC	shoot dry wt	19	400				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	NOEC	Chl a b mg	26	400				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	NOEC	shoot length	26	600				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	NOEC	Chl a b mg	105	800				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	NOEC	shoot dry wt	26	1000				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	NOEC	shoot length	105	1000				x		Davies 2007
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	LOEC	Chl a b mg	19	400						Davies et al. 2003
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	LOEC	Chl a b mg	26	1500						Davies et al. 2003
aquatic moss	*Fontinalis antipyretica*	21 days	Na2SO4	LOEC	Chl a b mg	105	1500						Davies et al. 2003
aquatic moss	*Fontinalis neomexicana*	14 days	Na2SO4		Chl a b mg	160	500						Beak and MTU 1998
diatom	*Nitzschia linearis*	5 days	Na2SO4	LC50	mortality	-	1285	1285	x		x		Patrick et al. 1968
diatom	*Nitzschia linearis*	5 days	CaSO4	LC50	mortality	-	2257			x	x		Patrick et al. 1968
Eurasian milfoil	*Myriophyllum spicatum*	32 days	Na2SO4	EC50	growth	-	2785	2785	x				Stanley 1974
Eurasian milfoil	*Myriophyllum spicatum*	32 days	Na2SO4	EC50	growth	-	6339		x				Stanley 1974
Eurasian milfoil	*Myriophyllum spicatum*	32 days	Na2SO4	EC50	growth	-	6915		x				Stanley 1974
Eurasian milfoil	*Myriophyllum spicatum*	32 days	Na2SO4	EC50	growth	-	7011		x				Stanley 1974
fathead minnow	*Pimephales promelas*	7 days	Na2SO4	IC25	growth	100	2255						BC Research
fathead minnow	*Pimephales promelas*	7 days	Na2SO4	IC50	growth	100	3450						BC Research
fathead minnow	*Pimephales promelas*	7 days	Na2SO4	LC50	mortality	100	1355						BC Research
fathead minnow	*Pimephales promelas*	7 days	Na2SO4	LOEC	survival	100	1060						BC Research
fathead minnow	*Pimephales promelas*	7 days	Na2SO4	LOEC	growth	100	3650						BC Research
fathead minnow	*Pimephales promelas*	7 days	Na2SO4	MATC	survival	100	735	735			x		BC Research
fathead minnow	*Pimephales promelas*	7 days	Na2SO4	MATC	growth	100	1967				x		BC Research
fathead minnow	*Pimephales promelas*	7 days	Na2SO4	NOEC	survival	100	510						BC Research
fathead minnow	*Pimephales promelas*	7 days	Na2SO4	NOEC	growth	100	1060						BC Research
green alga	*Chlorella vulgaris*	30 days	CaSO4		population growth	-	1056			x			Becker and Keller 1973
green alga	*Chlorella vulgaris*	30 days	CaSO4		population growth	-	1321			x			Becker and Keller 1973
green alga	*Chlorella vulgaris*	91.3 days	MgSO4	LOEC	population growth	-	982		x		x		Den Dooren de Jong 1965
green alga	*Chlorella vulgaris*	91.3 days	MgSO4	MATC	population growth	-	876	876			x		Den Dooren de Jong 1965
green alga	*Chlorella vulgaris*	91.3 days	MgSO4	NOEC	population growth	-	782		x		x		Den Dooren de Jong 1965

Table D.2: Summary of long-term effects of sulphate in a variety of aquatic organisms. Shade indicates lowest species threshold or lowest effect concentration at test hardness at or near 100 mg/L.

Common Name	Scientific Name	Duration (days)	Sulphate Type	Endpoint	Effect	Hardness (mg/L)	Sulphate Ion Effect Conc (mg/L)	Sulphate Effect Concentration at 100 mg/L hardness[1]	Presented by Singleton (2000)	Not Checked by Singleton	Data checked by Minnow	Used for Deriving Hardness Relationship (Table E.3)	Reference
green alga	*Pseudokerchneriella subcapitata*	3 days	Na2SO4	IC25	growth	100	2210	2210					BC Research
green alga	*Pseudokerchneriella subcapitata*	3 days	Na2SO4	IC50	growth	100	3359	3359					BC Research
green alga	*Pseudokerchneriella subcapitata*	3 days	Na2SO4	LOEC	growth	100	3650	3650					BC Research
green alga	*Pseudokerchneriella subcapitata*	3 days	Na2SO4	MATC	growth	100	1967	1967			x		BC Research
green alga	*Pseudokerchneriella subcapitata*	3 days	Na2SO4	NOEC	growth	100	1060	1060					BC Research
green alga	*Pseudokerchneriella subcapitata*	3 days	Na2SO4	IC50	growth	0	1868						BCMELP 2006
green alga	*Pseudokerchneriella subcapitata*	3 days	Na2SO4	LOEC	growth	0	1111						BCMELP 2006
green alga	*Pseudokerchneriella subcapitata*	3 days	Na2SO4	MATC	growth	0	641						BCMELP 2006
green alga	*Pseudokerchneriella subcapitata*	3 days	Na2SO4	NOEC	growth	0	370						BCMELP 2006
rainbow trout	*Oncorhyncus mykiss*	7 days	Na2SO4	EC25	viability	100	1280	1280					BC Research
rainbow trout	*Oncorhyncus mykiss*	7 days	Na2SO4	EC50	viability	100	1477	1477					BC Research
rainbow trout	*Oncorhynchus mykiss*	7 days	Na2SO4	LOEC	e test	100	3500	3500					BC Research
rainbow trout	*Oncorhynchus mykiss*	7 days	Na2SO4	MATC	etest	100	1926	1926			x		BC Research
rainbow trout	*Oncorhynchus mykiss*	7 days	Na2SO4	NOEC	etest	100	1060	1060					BC Research
rainbow trout	*Oncorhynchus mykiss*	7 days	Na2SO4	EC50	early life stage	25	1105					x	BCMELP 2006
rainbow trout	*Oncorhynchus mykiss*	7 days	Na2SO4	EC50	early life stage	100	1925	1925				x	BCMELP 2006
rainbow trout	*Oncorhynchus mykiss*	7 days	Na2SO4	EC50	early life stage	250	3116					x	BCMELP 2006
water flea	*Ceriodaphnia*	7 days	Na2SO4	IC25	reproduction	100	1267	1267					BC Research
water flea	*Ceriodaphnia*	7 days	Na2SO4	IC50	reproduction	100	2061	2061					BC Research
water flea	*Ceriodaphnia dubia*	7 days	Na2SO4	LC50	mortality	100	1967	1967					BC Research
water flea	*Ceriodaphnia*	7 days	Na2SO4	LOEC	survival/repro	100	3650	3650					BC Research
water flea	*Ceriodaphnia*	7 days	Na2SO4	MATC	survival/repro	100	1967	1967			x		BC Research
water flea	*Ceriodaphnia*	7 days	Na2SO4	NOEC	survival/repro	100	1060	1060					BC Research
water flea	*Daphnia magna*	21 days	Na2SO4	IC25	reproduction	100	833	833				x	BC MELP 2006
water flea	*Daphnia magna*	21 days	Na2SO4	IC25	reproduction	250	1476					x	BC MELP 2006
water flea	*Daphnia magna*	21 days	Na2SO4	LOEC		100	1200	1200					BC MELP 2006
water flea	*Daphnia magna*	21 days	Na2SO4	LOEC		250	1375						BC MELP 2006

[1] For species tested at different reported water hardness, effect concentration was adjusted to hardness 100 mg/L using the following equation: EXP(LN(EFFECT conc)-(0.788)*(LN(measured water hardness)-LN(100)))

Note: 0.788 is the slope for all species combined (short-term and long-term)

Lowest threshold toxicity value for species.

APPENDIX E

Hardness – Toxicity Relationships For Zinc, Cadmium and Sulphate

Table E.1: Data used to develop hardness-zinc toxicity relationships for long-term exposures to zinc.

Family	Species Common Name	Scientific Name	Duration	Endpoint	Life Stage	Observed Effect	Test Hardness (mg/L)	Effect Concentration (µg/L)	Mean Effect Concentration if Applicable (ug/L)	pH	Author(s)	Year
Algae	Green Algae	*Pseudokirchneriella subcapitata*	72 h	EC50	Population	biomass	212.4	17.5	←	7.5	Heijerick et al.	2002
			72 h	EC50	Population	biomass	212.4	34.4	←	7.5	Heijerick et al.	2002
				Mean EC50					24.5			
			72 h	EC50	Population	biomass	162.3	15.4	←	7.5	Heijerick et al.	2002
			72 h	EC50	Population	biomass	162.3	33.2	←	7.5	Heijerick et al.	2002
				Mean EC50					22.6			
			72 h	EC50	Population	biomass	112.3	14.9	←	7.5	Heijerick et al.	2002
			72 h	EC50	Population	biomass	112.3	27.9	←	7.5	Heijerick et al.	2002
				Mean EC50					20.4			
			72 h	EC50	Population	biomass	62.3	10.9	←	7.5	Heijerick et al.	2002
			72 h	EC50	Population	biomass	62.3	11.1	←	7.5	Heijerick et al.	2002
				Mean EC50					11.0			
			72 h	EC50	Population	biomass	37.2	8.44	←	7.5	Heijerick et al.	2002
			72 h	EC50	Population	biomass	37.2	10.5	←	7.5	Heijerick et al.	2002
				Mean EC50					9.41			
			72 h	EC50	Population	biomass	262.6	54.9		7.5	Heijerick et al.	2002
Invertebrates	Water Flea	*Daphnia magna*	21 d	EC10	< 24 hrs	Reproduction - # young / adult	196.4	126		8.2	De Schamphelaere et al.	2005
			21 d	EC10	< 24 hrs	Reproduction - # young / adult	189.3	171		8	De Schamphelaere et al.	2005
			21 d	EC10	< 24 hrs	Reproduction - # young / adult	183.2	265		8	De Schamphelaere et al.	2005
			21 d	EC10	< 24 hrs	Reproduction - # young / adult	124.7	59.2		8.4	De Schamphelaere et al.	2005
			21 d	EC10	Not reported	Reproduction (1)	110	233	←	8	Heijerick et al.	2003
			21 d	EC10	Not reported	Reproduction (1)	110	557	←	8	Heijerick et al.	2003
				Mean EC10					360			
			21 d	EC10	Not reported	Reproduction (1)	240	634		8.5	Heijerick et al.	2003
			21 d	EC10	Not reported	Reproduction (1)	370	600	←	8	Heijerick et al.	2003
			21 d	EC10	Not reported	Reproduction (1)	370	90	←	8	Heijerick et al.	2003
				Mean EC10					232			
			50 d	IC10	< 24 hrs	Reproduction - Brood size	51.9	29.8	←	8.39	Paulauskis and Winner	1988
			50 d	IC10	< 24 hrs	Reproduction - Brood size	51.9	32.8	←	8.39	Paulauskis and Winner	1988
			50 d	IC10	< 24 hrs	Reproduction - Brood size	51.9	55.7	←	8.39	Paulauskis and Winner	1988
				Mean IC10					37.9			
			50 d	IC10	< 24 hrs	Reproduction - Brood size	101.8	65.8		8.32	Paulauskis and Winner	1988
			50 d	IC10	< 24 hrs	Reproduction - Brood size	197	158	←	8.29	Paulauskis and Winner	1988
			50 d	IC10	< 24 hrs	Reproduction - Brood size	197	214	←	8.29	Paulauskis and Winner	1988
				Mean IC10					184			
			21 d	EC10	Population	Population growth inhibition	225	420		8.1	Enserink et al.	1991
			21 d	EC16	< 24 hrs	Reproduction - Number of young per survivor	49	70		7.4-8.2	Biesinger and Christensen	1972
				IC10	< 48 hrs	Reproduction - Number of young per adult	64.9	67.6		7.6-7.8	Münzinger and Monicelli	1991
		Ceriodaphnia dubia	7 d	ChV	24hrs	Reproduction - Brood size	169	105		7.8-8.2	Masters et al.	1991
			4 weeks	MATC	< 24 hrs	Reproduction - Number of young per adult	97.6	35	←	9	Belanger et Cherry	1990
			4 weeks	MATC	< 24 hrs	Reproduction - Number of young per adult	113.6	71	←	6, 8, 9	Belanger et Cherry	1990
			4 weeks	Mean MATC	24hrs	Reproduction- Number of young per adult	106		50			
			4 weeks	MATC	24hrs	Reproduction - Number of young per adult	182	71		8	Belanger et Cherry	1990
	Amphipod	*Hyalella azteca*	7 d	LC50	1- 11 days	Mortality (1)	18	56	←	6.44-8.68	Borgmann et al	2005
			7 d	LC50	1- 11 days	Mortality (1)	18	70	←	6.44-8.68	Borgmann et al	2005
			7 d	Mean LC50	1- 11 days	Mortality (1)			63			
			7 d	LC50	1- 11 days	Mortality (1)	124	222		7.23-8.98	Borgmann et al	2005
Fish	Rainbow Trout	*Oncorhynchus mykiss*	30 d	LC10	Juvenile	Mortality (1)	31.72	34.5		7.58-7.87	De Schamphelaere and Janssen	2004
			30 d	LC10	Juvenile	Mortality (1)	104.99	171		7.58-7.87	De Schamphelaere and Janssen	2004
			30 d	LC10	Juvenile	Mortality (1)	190.35	290		7.58-7.87	De Schamphelaere and Janssen	2004
			30 d	LC10	Juvenile	Mortality (1)	398.68	337		7.58-7.87	De Schamphelaere and Janssen	2004
			30 d	LC10	Juvenile	Mortality (1)	29.6	38.4	←	7.45	De Schamphelaere and Janssen	2004
			30 d	LC10	Juvenile	Mortality (1)	29.1	46.1	←	7.65	De Schamphelaere and Janssen	2004
			30 d	LC10	Juvenile	Mortality (1)	29.1	73.6	←	7.58	De Schamphelaere and Janssen	2004
				Mean LC10			29.3		50.7			
			30 d	LC10	Juvenile	Mortality (1)	29.1	99.1	←	6.78	De Schamphelaere and Janssen	2004
			30 d	LC10	Juvenile	Mortality (1)	28.2	185	←	6.8	De Schamphelaere et al.	2005
				Mean LC10					135			
			30 d	LC10	Juvenile	Mortality (1)	31.5	219		7.08	De Schamphelaere et al.	2005
			30 d	LC10	Juvenile	Mortality (1)	176.3	578		8.13	De Schamphelaere et al.	2005
			30 d	LC10	Juvenile	Mortality (1)	103.7	902		7.76	De Schamphelaere et al.	2005
	Fathead Minnow	*Pimephales promelas*	32 d	ChV	Larva	Mortality	47	188		7.4-8.2	Norberg-King	1989
			7 d	LC50	Larva	Mortality	190	780		8.3-8.7	Magliette et al.	1995
			NR	MATC	Egg	Mortality	46	207		7-8	Benoit and Holcombe	1978
			7 d	MATC	Larva	Mortality	48	125			Norberg and Mount	1985
			7 d	TLM	Fry	Mortality	186	870		7.5-7.6	Pickering and Vigor	1965

"← " values included in mean

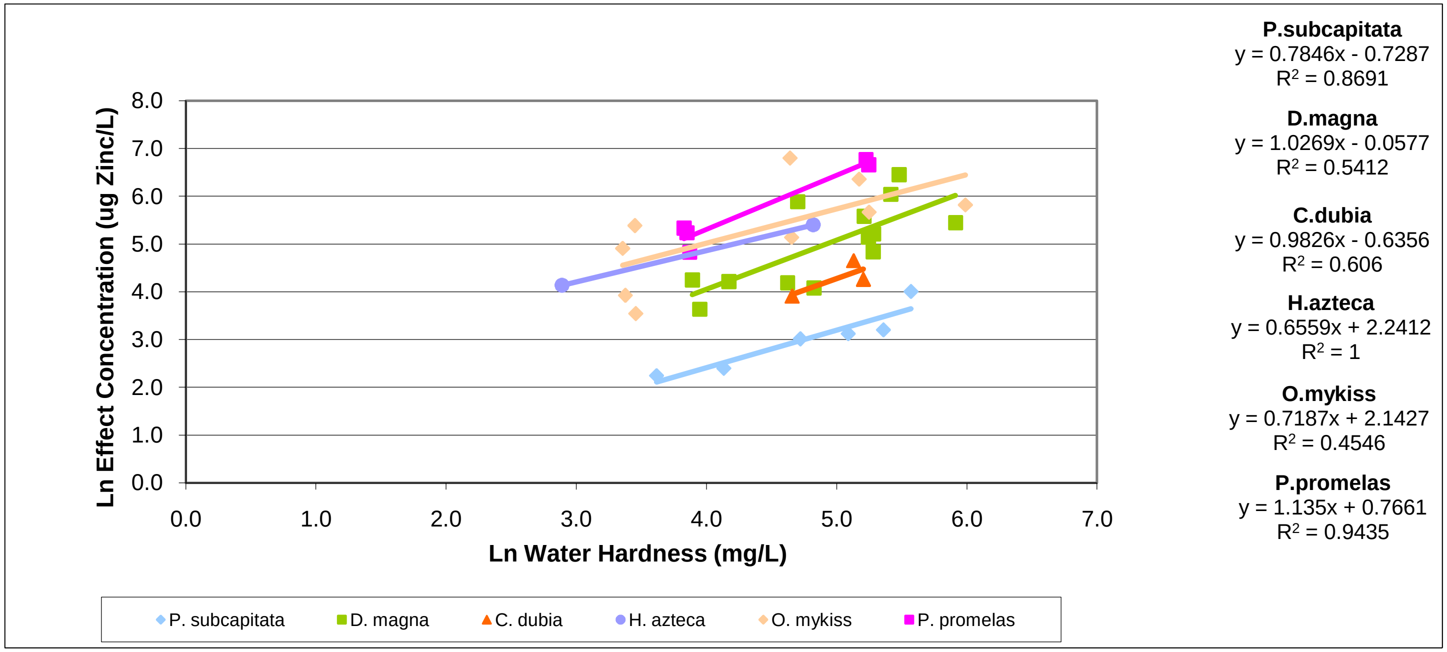


Figure E.1: Comparison of zinc hardness-toxicity relationships for various aquatic species in long-term exposures. Data in Appendix Table E.1.

Table E.2: Data used to develop hardness-cadmium relationships for long-term exposure to cadmium.

Family	Species Common Name	Scientific Name	Duration	Endpoint	Life stage	Observed Effect	Average Hardness	Effect Concentration (ug/L)	Mean Effect Concentration if Applicable (ug/L)	pH	Authors	Year
Algae	Green Algae	*Pseudokirchneriella subcapitata*	72 h	EC10	Population	Growth rate	3.42	2.8	←	6.71	Kallqvist	2007
			72 h	EC10	Population	Growth rate	6.21	7.5	←	6.85	Kallqvist	2007
			72 h	EC10	Population	Growth rate	16.21	8.5	←	6.74	Kallqvist	2007
			72 h	EC10	Population	Growth rate	46.21	6	←	6.65	Kallqvist	2007
							18.01		5.7			
			72 h	EC50	Population	Growth	250	43.5		8.1	Benhra et al.	1997
Invertebrates	Water Flea	*Daphnia magna*	21 d	EC16	Less than 24hrs	Reproduction	45.3	0.17		7.74 (7.4-8.2)	Biesinger and Christensen	1972
			21 d	MATC	Less than 24hrs	Reproduction - Number of young per adult	53	0.15		7.5 +- 0.2	Chapman et al	1980
			7 d	MATC	Neonate	Growth	90	1.2			Winner	1988
			21 d	MATC	Not reported	Reproduction - Number of young per adult	130	0.64			Borgmann et al	1989
			7 d	EC10	Adult	Repro - brood mass	179	0.13		8.07 +- 0.07	Barata and Baird	2000
			21 d	MATC	24h	Reproduction	249.8	1.09		8.0 +- 0.2	Kuhn et al	1989
			14 d	MATC	Less than 24hrs	Reproduction - Number of young per adult	240	4.3		8.0 +- 0.3	Elnabarawy et al	1986
Fish	Brown Trout	*Salmo trutta*	30 d	IC20	Swim-up fry	Biomass, decrease in	29.2	0.87		7.54 (0.13)	Brinkman and Hansen	2007
			61 d	MATC	Larva	Biomass, decrease in	45	2	←	7.6 (7.2-7.8)	Eaton et al.	1978
			60 d	MATC	Larva	Biomass, decrease in	45	6.7	←	7.6 (7.2-7.8)	Eaton et al.	1978
				mean MATC			**45**		3.7			
			30 d	IC20	Swim-up fry	Biomass, decrease in	67.6	2.18		7.60 (0.10)	Brinkman and Hansen	2007
			30 d	IC20	Swim-up fry	Biomass, decrease in	151.0	6.62		7.51 (0.12)	Brinkman and Hansen	2007
			50 d	ChV	Embryo-larval		250	16.49			Brown et al. (as cited by EPA 2001)	1994

"←" values included in mean

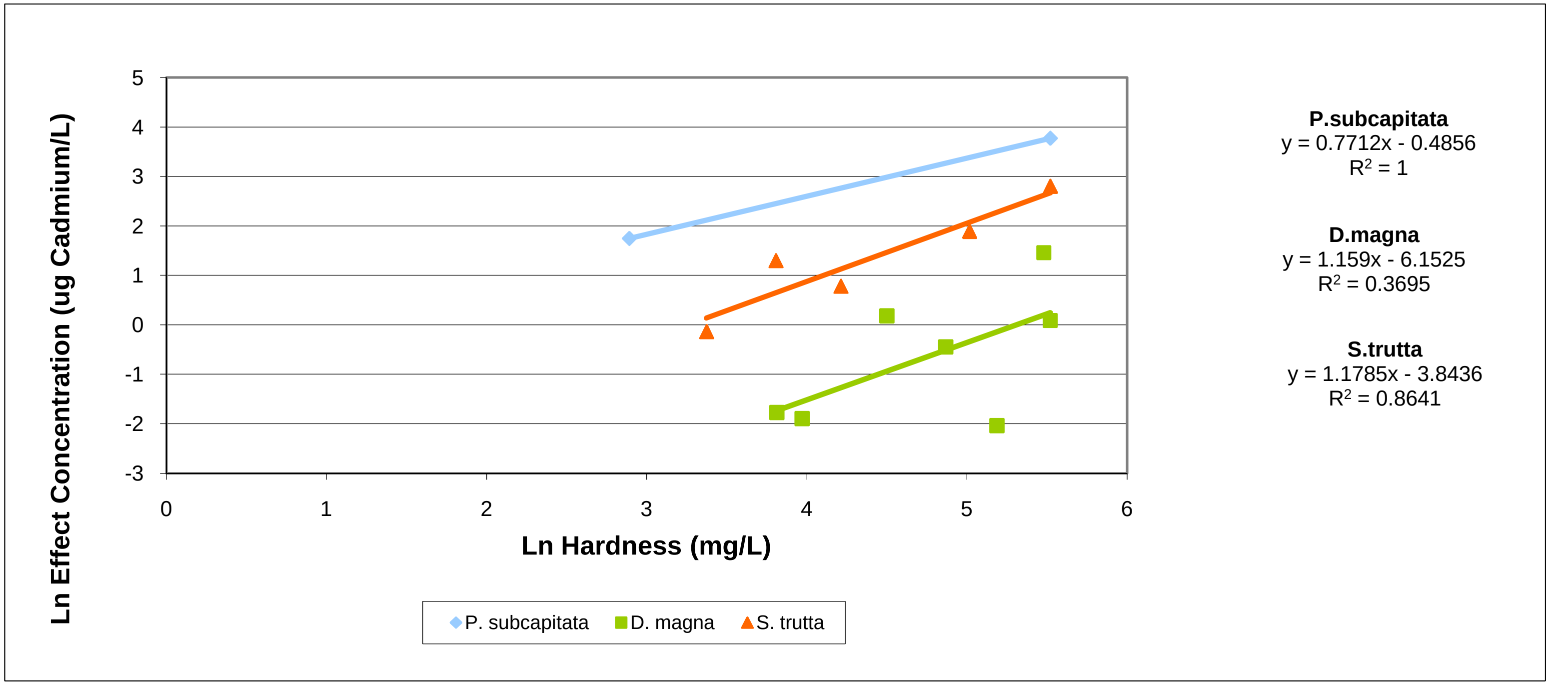


Figure E.2: Comparison of cadmium hardness-toxicity relationships for various aquatic species in long-term exposures (Data in Appendix Table E.2).

Table E.3: Data used to develop hardness-sulphate toxicity relationships for long-term exposure to sulphate.

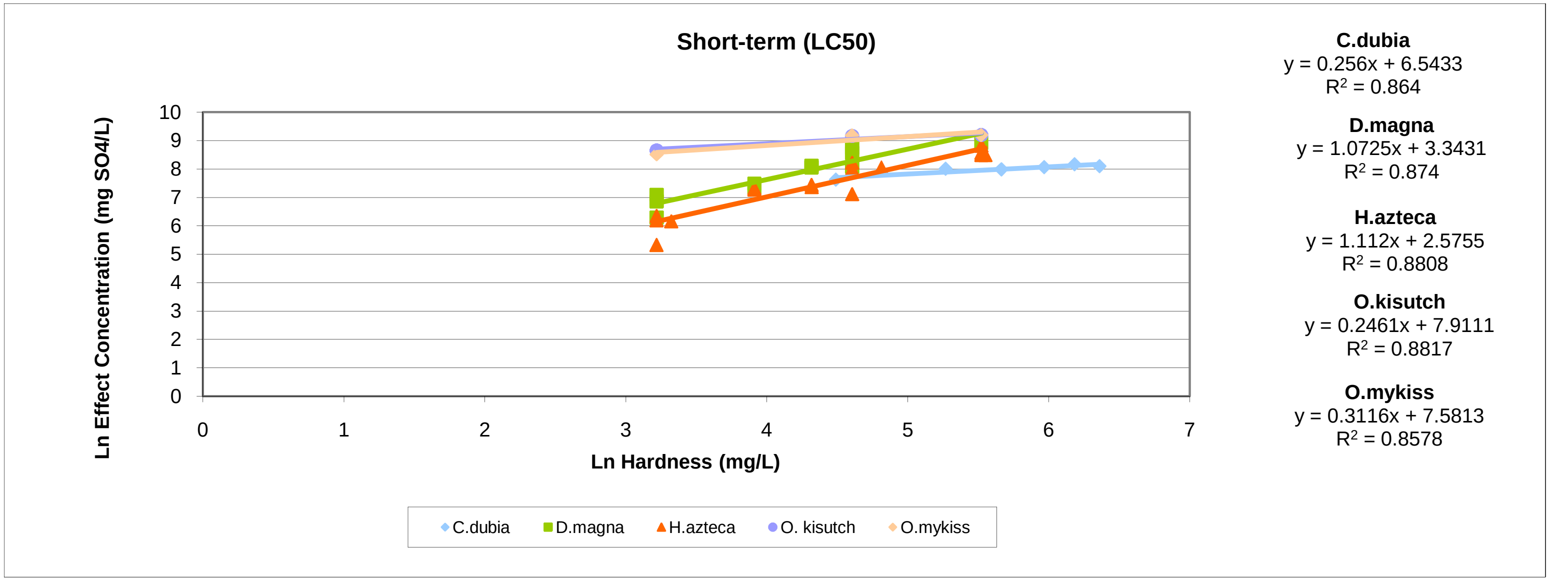
Long-term

Family	Species Common Name	Species Scientific Name	Duration (days)	Endpoint	Observed Effect	Test Hardness (mg/L)	Effect Concentration (mg/L)	Mean Effect Concentration if Applicable (mg/L)	Reference
Plant	Aquatic Moss	*Fontinalis antipyretica*	21 days	MATC	shoot length	19	400	←	Davies 2007
			21 days	MATC	shoot length	26	800	←	Davies 2007
						23		566	mean
			21 days	MATC	shoot length	105	1500		Davies 2007
Invertebrate	Water Flea	*Daphnia magna*	21 days	IC25	reproduction	100	833		BC MELP 2006
			21 days	IC25	reproduction	250	1476		BC MELP 2006
Fish	Rainbow Trout	*Oncorhynchus mykiss*	7 days	EC50	early life stage	25	1105		BCMELP 2006
			7 days	EC50	early life stage	250	3116		BCMELP 2006
			7 days	EC50	early life stage	100	1925		BCMELP 2006

Short-term

Family	Species Common Name	Species Scientific Name	Duration (days)	Endpoint	Observed Effect	Test Hardness (mg/L)	Effect Concentration (mg/L)	Mean Effect Concentration if Applicable (mg/L)	Reference
Invertebrates	Amphipod	*Hyalella azteca*	4 days	LC50	mortality	25	205		BC MELP 1996
			4 days	LC50	mortality	100	3711		BC MELP 1996
			4 days	LC50	mortality	250	6787		BC MELP 1996
			4 days	LC50	mortality	100	1226		BC Research
			4 days	LC50	mortality	30.5	453	←	Davies 2001
			4 days	LC50	mortality	25	491	←	Davies 2001
						27.8		472	mean
			4 days	LC50	mortality	75	1700		Davies 2001
			4 days	LC50	mortality	50	1518		Davies 2001
			4 days	LC50	mortality	123	2971		Davies 2001
			4 days	LC50	mortality	257	4864		Davies 2001
			4 days	LC50	mortality	25	491		Davies et al. 2003
			4 days	LC50	mortality	250	4864		Davies et al. 2003
			4 days	LC50	mortality	100	2971		Davies et al. 2003
			4 days	LC50	mortality	25	569		Davies and Hall 2007
			4 days	LC50	mortality	75	1580		Davies and Hall 2007
			4 days	LC50	mortality	50	1448		Davies and Hall 2007
			4 days	LC50	mortality	123	3144		Davies and Hall 2007
			4 days	LC50	mortality	250	5259		Davies and Hall 2007
		Ceriodaphnia dubia	2 days	LC50	mortality	578	3288		Soucek and Kennedy 2005
			2 days	LC50	mortality	484	3516		Soucek and Kennedy 2005
			2 days	LC50	mortality	390	3174		Soucek and Kennedy 2005
			2 days	LC50	mortality	288	2946		Soucek and Kennedy 2005
			2 days	LC50	mortality	194	3000		Soucek and Kennedy 2005
			2 days	LC50	mortality	89	2050		Soucek and Kennedy 2005
		Daphnia magna	2 days	LC50	mortality	25	537		BC MELP 1996
			2 days	LC50	mortality	250	7442		BC MELP 1996
			2 days	LC50	mortality	100	6281		BC MELP 1996
			2 days	LC50	mortality	100	5218		BC Research
			2 days	LC50	mortality	50	1551		Davies and Hall 2007
			2 days	LC50	mortality	25	1194		Davies and Hall 2007
			2 days	LC50	mortality	100	3203		Davies and Hall 2007
			2 days	LC50	mortality	75	3342		Davies and Hall 2007
			2 days	LC50	mortality	25	957		Davies et al. 2003
			2 days	LC50	mortality	50	1768		Davies et al. 2003
			2 days	LC50	mortality	75	3155		Davies et al. 2003
Fish	Coho Salmon	*Oncorhynchus kisutch*	4 days	LC50	mortality	250	9875		BC MELP 1996
			4 days	LC50	mortality	100	9550		BC MELP 1996
			4 days	LC50	mortality	25	5742		BC MELP 1996
	Rainbow Trout	*Oncorhynchus mykiss*	4 days	LC50	mortality	250	9900		BC MELP 1996
			4 days	LC50	mortality	100	9750		BC MELP 1996
			4 days	LC50	mortality	25	5000		BC MELP 1996

"←" value included in mean



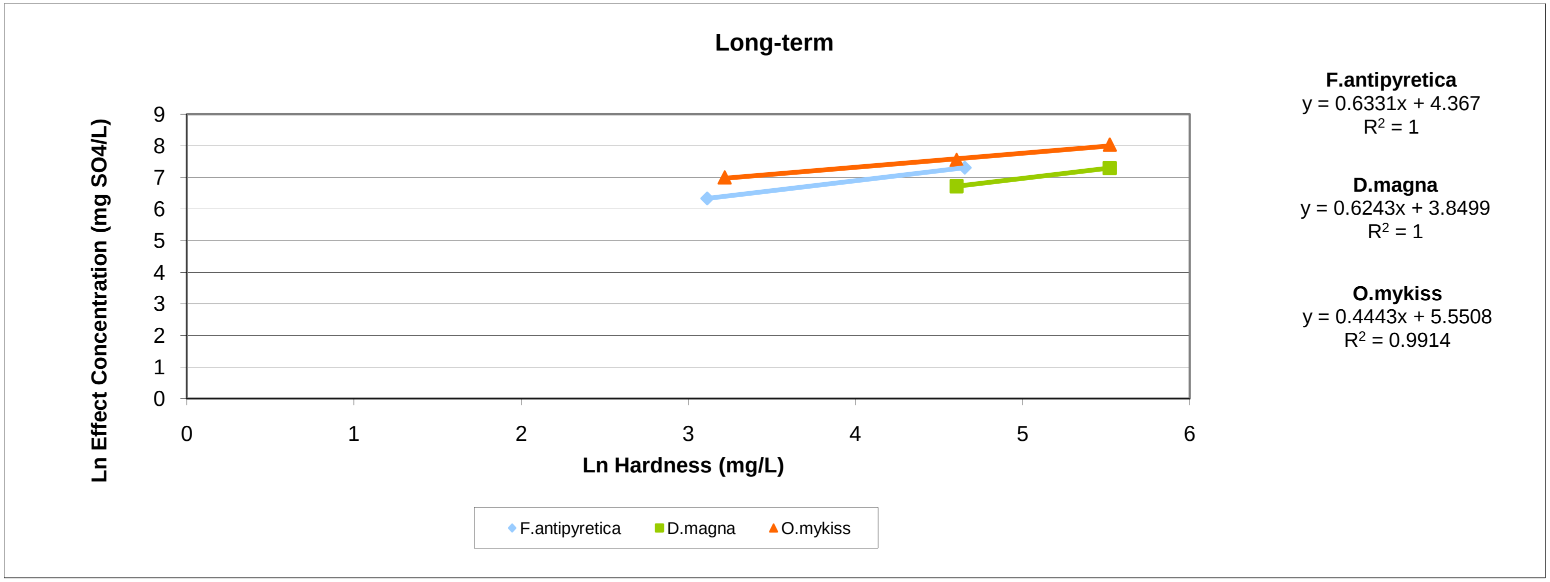


Figure E.3: Effects of sulphate in short-term (lethal) and longer-term exposures at different water hardness. Data in Appendix Table E.3.

Table E.4: Hardness-Toxicity Relationships for Sulphate, Zinc and Cadmium

Parameter	Species	n	Slope	*p*-value	r^2
Sulphate	Long-Term				
	Fontinalis antipyretica	2	0.633	-	1.000
	Daphnia magna	2	0.624	-	1.000
	Oncorhynchus mykiss	4	0.444	0.004	0.991
	Combined Long-term (p = 0.117)	8	0.514	0.000	0.980
	Short-Term				
	Hyallela azteca	17	1.112	0.000	0.881
	Ceriodaphnia dubia	6	0.256	0.007	0.864
	Daphnia magna	11	1.073	0.000	0.874
	Oncorhynchus kisutch	3	0.246	0.224	0.882
	Oncorhynchus mykiss	3	0.312	0.246	0.858
	Combined Short-term (p = 0.000)	40	0.837	0.000	0.808
	Combined Long- and Short-term (p = 0.000)	48	0.788	0.000	0.820
Zinc	*Pseudokirchneriella subcapitata*	6	0.785	0.007	0.869
	Daphnia magna	13	1.027	0.004	0.541
	Ceriodaphnia dubia	3	0.983	0.432	0.606
	Hyalella azteca	2	0.656	-	1.000
	Oncorhynchus mykiss	9	0.719	0.046	0.455
	Pimephales promelas	5	1.135	0.006	0.944
	Combined Slope (p = 0.909)	38	0.846	0.000	0.804
Cadmium	*Pseudokirchneriella subcapitata*	2	0.771	-	1.000
	Daphnia magna	7	1.159	0.148	0.370
	Salmo trutta	5	1.179	0.022	0.864
	Combined Slope (p = 0.830)	14	1.023	0.830	0.810