Reviewer	Affiliation	Reviewer Comment #	Page	Line	Comments & Questions	Response
Cameco	Cameco	1	ES	40-41	Rather than using natural or background hardness of the system to derive the cadmium water quality guideline, the hardness related to the exposure conditions should be used. This would allow reflectan accurate assessment of actual risk. If this is not completed, the guideline is irrelevant for that system and will either over or underestimate the risk to aquatic organisms. Furthermore, natural or background concentrations may not be know. It is not know that the use of background concentrations in this manner has been used elsewhere.	The statements suggesting that background hardness must be used have been removed. Site-specific assessments may be required in situations where conditions have be altered to determine if the WQG is appropriate.
Cameco	Cameco	2	13	24-27	Uncertainty factors are used to derive the guideline rather than the use of a species sensitivity distribution (SSD) approach, as per the CCME. The SSD approach is widely used throughout the world (e.g.,Canada and US). The use of the SSD would eliminate the need to apply professional judgement in order to select safety factors. It also results in guidelines that are overly conservative.	BC's protocol for developing water quality guidelines was used (http://www.env.gov.bc.ca/wat/wq/pdf/wq-derivation.pdf). BC does not use the SSD approach to derive WQGs. The SSD paradigm is not consistent with BC's guiding principles (i.e., protecting the most sensitive species and sensitive life stage indefinitely).
Cameco	Cameco	3	16	14-25	The document should reflect detection limits that are routinely available and used in commercial laboratories. This may differ from what detection limits may be available under research-type settings. This is particularly important considering that the analytical capabilities are at or very near the lower end of the draft guidelines associated with low hardness conditions. The uncertainty at the low levels should be discussed including how the guideline should be used when a measurement is below a detection limit that is at the guideline value.	Information was provided on typical detection limits achieved by methods in Section 3.0 of the document. Guidance on the selection of appropriate detection limits for evaluating water quality conditions relative to the WQG has been added to the revised document. While guidance on the use of non-detect data in evaluating water quality conditions is important, it is particular to the study question and beyond the scope of this document . Guidance on the treatment of non-detect data has been developed by Huston and Juarez-Colunga (2009) in conjunction with BCMOE. Huston, C. and E. Juarez-Colunga. 2009. Guidelines for computing summary statistics for data-sets containing non-detects. Prepared for the Bulkley Valley Research Center with assistance from BCMOE. January 19, 2009. 178 pp.
Cameco	Cameco	4	17	1-12	This section states that both dissolved and total cadmium should bemonitored. The guideline does not reflect the importance of both these measurements. The guideline should be revised to reflect this by providing a guideline that is based on total cadmium. This is what is typically analyzed, as outlined in the Draft Guideline.	As the dissolved fraction provides a better estimate of bioavailable cadmium (Campbell 1995; Paquin *et al.* 2002), the guideline will be based on the dissolved fraction. This is consistent with with other jurisdictions (e.g., USEPA).
Cameco	Cameco	5	18	4-7	Alkalinity and pH were listed previously as important factors to consider. Should these also be considered here when looking into background concentrations of cadmium?	While both alkalinity and pH are important factors to consider when evaluating water quality, limited data on alkalinity are available (though pH data are likely to be available). As hardness is the primary factor used in adapting the cadmium WQGs for site conditions, the evaluation of background conditions has been limited to cadmium and hardness.
Cameco	Cameco	6	51	28-51	This section of text seems out of place. Consider stating this up front in Section 7.0, if this is reflected in this entire section of the report.	This paragraph has been moved to the introduction of Section 7.0 as suggested by the reviewer.
Cameco	Cameco	7	55	15-22	Provide details on how the literature was acquired (e.g., when was the date of the last time a literature search was completed). This could be useful for subsequent revisions to the guideline and transparency.	Specific information on the sources and dates of the literature reviews have been added to the revised document.
Cameco	Cameco	8	69	30	The section on the application of water quality guidelines for cadmium should outline how data at or near the detection limit that is within 10 times the guideline value should be interpreted. This is a common scenario and should be addressed.	Guidance on the selection of approriate detection limits (i.e., a minimum of 5 times below the WQG or when available, practical quantitation limits at or below the WQG) for evaluating water quality conditions relative to the WQG has been added to Section 9.4 of the revised document.
Cameco	Cameco	9	70	30-33	Provide details of the availability of the sediment quality guidelines described here for cadmium by citing available references.	References to relevant sediment quality guidelines have been added to this statement and the table presented in the Executive Summary of the revised document.
Cameco	Cameco	10	71	10	The need for lower detection limits under routine, commercial laboratory conditions should be added to this section. This is an area of uncertainty and an area for improvement.	This is a good point to raise. As such, Section 9.4.5 (Research and Development Needs) has been revised to include a paragraph on the need for appropriate detection limits.

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Ryan Hill, Gary Mann, Patrick Allard	Azimuth Consulting Group Partnership	1	13	26-27	The draft states explicitly that for any case where water quality is affected by anthropogenic activities the guidelines must be applied using background (e.g., upstream) hardness, not hardness measured for the site. If we acknowledge that hardness modifies toxicity, there is no scientific rationale for using any hardness value other than that which co-occurs with the cadmium. We assume that the requirement to apply background hardness is included because of concern about hardness, not cadmium. If there is concern about hardness, then a guideline addressing hardness should be developed. Our recommendation is that the text be amended to clearly state that cadmium in a given water sample should be evaluated using corresponding hardness data applicable to the same sample. If similar text is anywhere else in the draft it should also be amended.	The statements suggesting that background hardness must be used have been removed. Site-specific assessments may be required in situations where conditions have be altered to determine if the WQG is appropriate.
Ryan Hill, Gary Mann, Patrick Allard	Azimuth Consulting Group Partnership	2	66 55 63 13	16 7-11 20-32 9-27	We agree that WQGs intended for generic application should be somewhat conservative. However, when WQGs are unreasonably conservative it creates additional, likely unwarranted work and costs for managers of sites (including taxpayers who are responsible for many historic industrial sites) and for proponents of industrial projects. We agree many types of uncertainties exist. We also agree that use of the lowest value and application of uncertainty factors (UFs) may be warranted for cases where data are sparse. However, the draft WQGs for cadmium are based on an extensive data set. In a large data set, the probability that the most sensitive data point is a correct reflection of expected response is actually quite low, and in fact there is a reasonable chance that the finding is actually false in the first place (Ioannidis 2005, PLoS Med v2(8)). For the long-term WQG for cadmium there were hundreds of data points from primary studies. Admittedly not all of these are for sensitive species, but in any case the lowest value among the data points, particularly when other data for that species or genus show less sensitivity, is likely conservative. Application of a further UF to that data point could be expected to result in an even more conservative WQG depending on how the UF is derived. The UF of 3.0 that was applied to derive the long-term WQG seems unreasonable (relative to current science-based approaches by CCME and other jurisdictions) when it is applied to the most sensitive among hundreds of data points.	A re-evaluation of the critical studies used to derive the long-term water quality guideline was conducted. Based on the re-evaluation, the uncertainty factor was revised from 3 to 2.
G. Larocque	APEGBC, Associate Director, Professional Practice	1	General		The Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) welcomes the opportunity to review and comment on the draft BC Ministry of Environment (MoEnv) ambient Water Quality Guidelines (WQG) for Cadmium[1]. Although APEGBC has not conducted a comprehensive review of the report, it has reviewed some of the key studies, procedures, and assumptions applied in the derivation, focussing on the technical aspects that are most directly linked to the numerical derivation of the WQG. 1 BC Ministry of Environment. Ambient Water Quality Guidelines for Cadmium – Technical Report. Water Protection and Sustainability Branch, Environmental Sustainability and Strategic Policy Division. June 2014	No response required.
G. Larocque	APEGBC, Associate Director, Professional Practice	2	Table ES-1 12	3	It could be clearer whether the WQG are intended for application to freshwater only (i.e., does the working guideline for marine water remain in effect, or does the maximum hardness value from Table ES-1 apply to marine waters?). The executive summary implies that marine waters are to be considered separately; if such is the case, it is suggested that the title of the document become "Freshwater Ambient Water Quality Guidelines for Cadmium". This explicit title would prevent confusion in the application of the guidelines, especially as the Introduction mentions "both fresh and marine surface waters of BC."	The executive summary has been revised to explicitly state that the derived WQGs should be applied to freshwater systems. As the working marine WQGs and sediment quality guidelines (SQGs) have been presented in the document, no changes to the title have been made.
G. Larocque	APEGBC, Associate Director, Professional Practice	3	General		APEGBC is fully supportive of the Ministry's policy of developing science-based guidelines for the protection of aquatic life, and recognizes that such guidelines intended to safeguard the most sensitive species at their most delicate life-stages during both short-term and long-term exposures. The stated guiding principle that the WQG are "science-based" seems, at times, incongruent with the policy determinations used in the derivation. Many of the comments relate to the difficulty reconciling science and policy considerations in the WQG derivation. Some of the policy decisions do not appear to support, and at times may undermine, the development of "science-based" WQG.	BC's protocol for developing water quality guidelines was used (http://www.env.gov.bc.ca/wat/wq/pdf/wq-derivation.pdf). The approach to develop guidelines for aquatic life reflects the guiding principles that all forms of aquatic life and all aquatic stages of their life cycle are to be protected during indefinite exposure.
G. Larocque	APEGBC, Associate Director, Professional Practice	4	General		A common theme emerging from the review relates to the treatment of uncertainty in the WQG derivation. In the face of uncertainty, the draft WQG for Cadmium apply multiple, compounded layers of conservatism to the underlying scientific data. Although these layers are intended to provide a high degree of confidence that the WQG will satisfy the environmental protection goals, they have the effect of lowering the WQG to a value (near background in some cases) that is likely to be much lower than the true threshold for environmental response. The unintended consequence of applying overly conservative criteria is that the effectiveness of the WQG may be decreased a level where it would be difficult to reliably discriminate real environmental concerns, potentially resulting in misallocation of resources.	BC's protocol for developing water quality guidelines was used (http://www.env.gov.bc.ca/wat/wq/pdf/wq-derivation.pdf). The approach to develop guidelines for aquatic life reflects the guiding principles that all forms of aquatic life and all aquatic stages of their life cycle are to be protected during indefinite exposure. BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. Factors such as the presence of multiple stressors, information on partial life-cycles, delayed effects, and intra- or inter-species variabililty necessitates the need for an uncertainty factor to reduce the potential for risk to aquatic life. A re-evaluation of the critical studies used to derive both the short-term and long-term WQGs was conducted. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate for both the short-term and long-term WQGs.

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G. Larocque	APEGBC, Associate Director, Professional Practice	5	General		Consideration of only the single lowest reported effect concentration, rather than using all available data for the most sensitive species, is inconsistent with best practice in toxicology. A problem with this approach is that there is an inherent bias toward inclusion of false positives in the data set. Where false negatives are discounted (i.e. not used in the WQG derivation) because high-concentration endpoint values are effectively excluded from consideration, any value that passes the data screening criteria of Ministry guidance for derivation of water quality guidelines2 is eligible for use in the WQG derivation, even if the value is inconsistent with other testing results for the same species and endpoint. Anomalously low values may justifiably reflect high inter- or intra-species sensitivity to a substance; however, low values may also arise due to errors in the underlying effects data. Reliance on the lowest primary data point therefore conveys conservatism in the derivation, particularly when other chronic data are available for the most sensitive species. In the cadmium WQG derivation, the first factor of conservatism applied to the toxicological dataset is to select the lowest effect concentration from Hyalella azteca as the critical toxicity value. The toxicity dataset contains several independent measures of effects concentrations for H. azteca, any of which would be considered a valid estimate of an effects concentration for this species. Best practice in derivation of federal water quality guidelines in Canada and the United States is to combine these independent values by calculating a geometric mean, provided that the endpoints are compatible. This averaging procedure ensures that critical effects concentrations are supported by multiple comparable studies when such are available, reducing the influence of anomalously (and potentially erroneously) low values such as the results of Elnabarawy et al.3. Notably, the United States Environmental Protection Agency4 calculated a species mean chronic value of 0.275 µg/L for H. azteca (corrected to 50 mg/L hardness) and a species mean acute value of 2.108 µg/L for rainbow trout (corrected to 50 mg/L hardness). In contrast, the WQG adopt the single, lowest reported values (corrected to 50 mg/L hardness) of 0.137 µg/L for H. azteca and 0.578 µg/L for rainbow trout. Given the similarity in underlying data, this procedure essentially applies a two-fold factor of conservatism to the long-term WQG and a 3.6-fold factor of conservatism to the short-term WQG. The lowest effect endpoint procedure is a point of departure between provincial2 and federal5 guidance. Even where the provincial approach is followed, it is recommend that the distribution of effect data for the most sensitive species be explicitly considered when evaluating need for additional margins of safety. The draft WQG acknowledge the role of scientific judgement "to maintain some flexibility in the derivation process." It is believed is that the wealth of information available from the full compiled scientific data on cadmium toxicity could be incorporated in the WQG derivation in a more balanced manner.	All available data is reviewed and classified as primary, secondary or unacceptable. All acceptable data is considered when developing the WQG. Geomeans for species can be calculated for studies that have similar test conditions and the same life stage. BC's protocol for developing water quality guidelines was used (http://www.env.gov.bc.ca/wat/wq/pdf/wq-derivation.pdf). The approach to develop guidelines for aquatic life reflects the guiding principles that all forms of aquatic life and all aquatic stages of their life cycle are to be protected during indefinite exposure. All studies classified as primary and secondary were used to support the development of the WQGs. BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. A re-evaluation of the critical studies used to derive both the short-term and long-term WQGs was conducted. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate for both the short-term and long-term WQGs.
G. Larocque	APEGBC, Associate Director, Professional Practice	6	55	28	The WQG state that the categorization of studies into primary, secondary, or unacceptable categories was conducted "to ensure that only those studies that were scientifically sound and of high quality were used in the WQG derivation." The procedures applied appropriately followed Ministry guidance for derivation of water quality guidelines, and as such provide some degree of quality assurance. These guidelines, however, cover only a subset of the factors that affect overall technical quality of underlying toxicological data; the classification rules do not, by themselves, ensure high quality data. In particular, studies that generate effect concentrations close to the minimum low-effect threshold require additional careful review to gauge suitability for direct application in guideline derivation.	Agreed.
G. Larocque	APEGBC, Associate Director, Professional Practice	7	Figure 8		In Figure 8, three secondary studies are plotted at values close to the minimum low-effect threshold; these data points are all derived from a study by Elnabarawy et al.3. These studies have importance for the WQG derivation because they appear to inform the application of an uncertainty factor of 3.0. A review of the primary literature reveals several concerns with data quality in this study, particularly with respect to the values selected to represent low-effect threshold values: - The concentrations selected by the Ministry as the basis for low-effect threshold values are the lowest observed effect level (LOEC) estimates reported in Table 5 of Elnabarawy et al.3. These LOEC values are inconsistent with the source data presented in Table 3 of the same study. For example, the reported LOEC is 0.5 µg/L Cd for Daphnia magna, which is inconsistent with the observation that reproduction was actually higher than negative control performance at this test concentration. Adoption of this value as a low-effect threshold value is therefore erroneous, and should not be applied or considered in WQG derivation. - The LOEC estimates are not based on statistically significant outcomes from the underlying experiments in Elnabarawy et al.3; rather they are flawed estimates of EC16 values. The selected 16% response magnitude was developed in a completely distinct experimental design (Biesinger and Christensen6) and bears no relation to the statistical significance measures from Elnabarawy et al.3 Use of the IC16 is not supportable because: (1) the statistical power in Elnabarawy et al.3 was insufficient to detect responses of this magnitude; and (2) the calculations of the IC16 presented in the paper are suspect, as discussed below. - There appears to be a unit identification error in Table 3 of Elnabarawy et al.3; specifically, the tabulated concentrations of cadmium (listed as µg/L Cd) appear to represent the concentration of cadmium chloride (CdCl2). This error is significant because cadmium is only 61% of the molecular mass of cadmium chloride. This error has been identified from comparison of the statistical endpoint summaries in Table 5 to the raw data. In this review, the analysis conservatively assumes that the lower concentrations estimates apply.	The Elnabaraway *et al.* (1986) study was re-evaluated. Based on the re-evaluation, the IC16, NOEC, LOEC, and MATC were re-calculated after converting the concentrations from $CdCl_2$ to Cd (typographical error in the study). The revised IC_{16} values (calculated using linear interpolation and smoothed means, when necessary) are plotted in the revised Figures 8 and 9. However, these results were not used as the basis for the long-term WQG nor were they used in the development of the uncertainty factor due to the high uncertainty associated with the study.

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G. Larocque	APEGBC, Associate Director, Professional Practice	7 (cont'd)	Figure 8		- Even with the correction for the above error, additional inconsistencies and errors are apparent in the summary of test endpoints. As shown in APEGBC Figure 1 below, the IC16 values for both D. magna and D. pulex reported by the authors do not align with the raw data. This raises overall concerns about the quality of reported data. The interrupted concentration-response shape was not acknowledged in the LOEC derivation. The reported LOEC for D. pulex (0.2 µg/L Cd) is well below a test concentration (1.53 µg/L Cd) for which reproduction was shown to be identical to negative control. The reported LOEC is neither consistent with results from any individual treatment, nor matches any plausible model fit to the underlying data. The number and severity of errors in the primary data source confound the interpretation of the study. When combined with the lack of confirmed (measured) concentrations in the study, these errors could be used to justify exclusion of the study altogether. Even if the study is retained (with caveats), and corrected concentrations applied in endpoint derivation, the low-effect threshold for all three species (based on a response size of 20%) appears to be in the range of 1 – 2 µg/L Cd, rather than the range of 0.2 – 0.5 µg/L Cd as adopted by in the WQG. At minimum, Figure 8 should be updated to correct for these errors, and the need for an uncertainty factor reconsidered in light of these findings. Overall, the compilation of toxicity data in the WQG appears to follow sound scientific practice (with the exception of inclusion of some unreliable data, as discussed above). The identification of sensitive species and endpoints is similar to evaluations conducted by other jurisdictions (CCME, USEPA).	See above
G. Larocque	APEGBC, Associate Director, Professional Practice	8 (a)	65 69 13	32 4 23	The WQG discuss numerous theoretical sources of uncertainty, and concludes that "it is necessary to apply uncertainty factors" in the face of these uncertainties. This approach presumes that the presence of uncertain factors or processes would, on balance, increase rather than decrease risk. Page 13 lists nine sources of uncertainty that are used as a justification to apply an uncertainty factor in deriving a WQG. The problems with this approach are: - the potential for the identified factors to decrease, rather than increase, toxicity is not recognized; - conservative data-processing assumptions from the derivation procedures, which already account for some of the identified uncertainties, are not recognized; and - the evaluation of these sources of uncertainty in the document eliminates most of them as key sources of uncertainty when assessed in relation to cadmium. On the latter point, the document states that "indirect effects (due to bioaccumulation), toxicity of metabolites, and delayed toxicity do not represent key sources of uncertainty relative to the toxicity of cadmium" (p. 65). Furthermore, abundant toxicity data exist to identify the most sensitive species, life stage, and effect endpoint in long-term exposures. Potential joint (interactive) effects of multiple contaminants are specifically excluded from consideration (p. 69). With respect to laboratory-to-field differences, the WQG document cites Mebane7, which reports an extensive validation of laboratory data as predictive of effects due to cadmium in the environment. Following this review, the only remaining justifications for an uncertainty factor (according to the list on p. 13) relate to speculation about climate change and "other stressors including cumulative effects". Overall, the analysis of these factors for cadmium indicates a strong body of scientific information indicating low uncertainty relative to most other regulated water quality parameters.	It is agreed that some of the factors listed may decrease risk under certain situations; however, BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. A re-evaluation of the critical studies used to derive both the short-term and long-term WQGs was conducted. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate for both the short-term and long-term WQGs.
G. Larocque	APEGBC, Associate Director, Professional Practice	8 (b)			Despite a lack of evidence to support a need for additional margins of safety, the WQG conclude that other sources of uncertainty exist, such that an uncertainty factor of 3.0 is applied to the long-term WQG. In specifying this value, the WQG reference the IC_{25} of 0.137 for *Hyalella azteca* (the lowest of all available values for the most sensitive species), noting the lack of a reported confidence interval in the primary study. No rationale is provided for the selection of this specific number, other than an "assumption that the associated error would be less than 3.0 times the effect value."	BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. A re-evaluation of the critical studies used to derive the long-term WQG was conducted. Based on the re-evaluation, the uncertainty factor was reduced from 3 to 2.
G. Larocque	APEGBC, Associate Director, Professional Practice	8 (c)	67	26	The first issue with the uncertainty factor, as discussed in Comment APEGBC 05 above, is that the available technical data for *H. azteca* indicate lower, not greater, overall sensitivity of this species to cadmium than is suggested by the single most sensitive endpoint result. Mebane[7] confirms that *H. azteca* "is the most consistently sensitive species, with seven hardness-adjusted values ranging from 0.14 to 0.51 µg/L." Mebane[7] derives a geometric mean chronic value (0.33 µg/L) for developing a benchmark applicable to this sensitive species, lifestage, and endpoint. Choosing the lowest individual result, while also applying an uncertainty factor to account for unknown variance around this single value, is being doubly conservative where such is not required. The other *H. azteca* chronic toxicity data provide the necessary confidence that use of the lowest individual result is already protective.	BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. A re-evaluation of the critical studies used to derive the long-term WQG was conducted. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate.
G. Larocque	APEGBC, Associate Director, Professional Practice	8 (d)			A second issue with the uncertainty factor is that there are other lines of evidence available that suggest lack of need for the additional conservatism. Mebane[7] evaluatec empirical field data and population modelling results for *H. azteca* as a means of validating the protectiveness of various cadmium concentrations for this sensitive species. For example: - Monitoring in the Coeur d'Alene and Clark Fork River provide evidence of amphipods being present in environments with cadmium concentrations that are near or exceed 0.41 µg/L (hardness-adjusted to 50 mg/L CaCO3). These concentrations provide evidence that "in field conditions, H. azteca populations may be resilient" to cadmium concentrations, including those an order of magnitude greater than the hardness-adjusted WQG of 0.046 µg/L. - Population-level effects of cadmium to H. azteca were evaluated using life-stage or age structured matrix projection models (Mebane7). Although populations could be limited by cadmium at the US EPA chronic criterion 0.41 µg/L (hardness-adjusted to 50 mg/L CaCO3), they were unlikely to be of a magnitude that would result in local extinctions. Concentrations representing the minimum low-effect threshold to H. azteca would have even lower risks. Although biomonitoring and population models have their own sources of uncertainty, the above findings should be taken into consideration when evaluating whether, and to what degree, an uncertainty factor is warranted when the lower effect endpoint is required.	BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. A re-evaluation of the critical studies used to derive the long-term WQG was conducted. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate.

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G. Larocque	APEGBC, Associate Director, Professional Practice	8 (e)	Figure 8		A third issue with the uncertainty factor of 3.0 relates to the arbitrary value selected. From visual inspection of Figure 8, it appears that the value may have been selected to capture the secondary study results with cadmium concentrations below the minimum low-effect threshold. Although it does not appear to be explicitly stated in the WQG, the general procedure for WQG derivation normally takes into consideration the secondary study results in the evaluation of uncertainty factors. Because the secondary study data presented in Figure 8 are erroneous, any uncertainty factor based in part on those data needs to be re-examined.	BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. A re-evaluation of the critical studies used to derive the long-term WQG was conducted. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate.
G. Larocque	APEGBC, Associate Director, Professional Practice	8 (f)	64	7-12	An uncertainty factor is also applied to the short-term WQG, but based on a different rationale. For the short-term WQG, the critical toxicity value is an LC_{50} for rainbow trout. The WQG derivation converts this LC_{50} to an LC_{10}, such that the short-term WQG will identify the potential for acute lethality (at a low-effect level) under short-term exposures. This is an appropriate procedure, but it is not conducted in a quantitatively defensible way. The WQG cite paired LC_{50} and LC_{10} values from six experiments (p. 64). One way to develop a conversion factor from these data would apply regression analysis, as illustrated in APEGBC Figure 2 below. The LC_{50} / ratio derived by regression analysis (the inverse of the slope shown on Figure 2) is 1.48. An alternative would be to calculate the LC_{50}/LC_{10} ratio from each of the six experiments, and then take an average of these values as the scientific best estimate of the true ratio. The WQG adopt neither of these approaches, choosing instead to select an uncertainty factor of 3.5 to the short-term; this value falls outside the range of values observed in the data (1.3 to 3.1). The applied uncertainty factor is 2.4-fold higher than necessary to convert the critical toxicity value (the lowest of all available values for the most sensitive species) to an LC_{10}, and introduces an additional source of conservatism in WQG derivation.	BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. A re-evaluation of the critical studies used to derive the short-term WQG was conducted. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate.
G. Larocque	APEGBC, Associate Director, Professional Practice	8 (g)			Overall, whereas application of uncertainty factors decreases the probability of a false negative (Type II error), it increases the probability of a false positive (Type I error). In other words, the screening of water quality data to WQG that incorporate excessive uncertainty factors will generate a biased indication of actual potential for environmental harm. If the WQG criteria were applied only for initial screening of water quality data, to identify concentrations that are clearly and definitively not of concern, this would not necessarily be problematic. The proposed regulatory application of the WQG, however, comprises use beyond initial screening, including application to establishment of site-specific ambient water quality objectives, as a basis for evaluating environmental hazard in environmental impact statements, establishment of wastewater discharge limits, and other regulatory uses. In this context, the consequences of Type I errors must be considered.	We do not present a regulatory approach in the Cd WQG. WQGs do not have any direct legal standing. They are intended as a tool to provide policy direction to those making decisions affecting water quality. BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty.
G. Larocque	APEGBC, Associate Director, Professional Practice	9	11; Table 5	39	The WQG state that, in recognition of other toxicity modifying factors (besides hardness) for cadmium toxicity, "due care should applied in systems in which hardness is influenced by anthropogenic activities." Requiring such calculations from background hardness, rather than the hardness that co-occurs with the cadmium concentrations in question, is contrary to fundamental toxicological principles. The WQG document demonstrates convincingly (as have similar documents in other jurisdictions) that cadmium toxicity is strongly modified by the hardness of the water in which exposure occurs. In essence, the WQG procedure considers a theoretical scenario in which cadmium exposure is considered in terms of potential toxicity, but site-relevant toxicity modifying properties appears to be set aside. APEGBC understands that the above procedure is an example of provincial policy concerning the handling of toxicity modifying factors. For example, Guidance for the Derivation and Application of Water Quality Objectives in British Columbia8 states that "when there are toxicity-modifying factors (ameliorating or aggravating) present, water quality objectives (WQO) are based on the natural background concentrations of these factors, not levels that have been altered due to human land use (e.g., hardness)." This procedure is grounded in policy rather than science. It is also inconsistent with the procedures used in other jurisdictions; for example, the CCME6 provides a formal acknowledgement of the role of toxicity modifying factors without requirement that background conditions be applied. On the other hand, the WQG do not provide evidence to support the hypothesis that anthropogenically-derived hardness is any different than background hardness in terms of modifying cadmium toxicity. Although it is true that factors other than hardness would influence cadmium bioavailability (e.g., dissolved organic carbon [DOC], pH, and alkalinity), such factors would not be biased toward greater toxicity potential in anthropogenically-affected waters. To the contrary, Mebane7 concludes that based on the result of several tests, cadmium is less toxic in effluent-influenced stream waters than it is in reconstituted test waters. The background hardness data summarized in the WQG document illustrate the additional factor of conservatism that this procedure imparts to the WQG. According to the compiled data, average background hardness in BC waters ranges from 19.7 mg/L (Vancouver Island) to 124 mg/L (Omenica-Peace). Thus, irrespective of the actual hardness present in waters at a site, the long-term cadmium WQG would be, on average, 0.0224 µg/L (Vancouver Island) to 0.091 µg/L (Omenica-Peace). For comparison, the calculated long-term WQG at hardness ≥285 mg/L is 0.172 µg/L. Thus, for a typical mine site with anthropogenically-elevated hardness, calculation of the WQG using background hardness imparts a factor of conservatism on the order of 1.9 (Omenica-Peace) to 7.7 (Vancouver Island) relative to a site-specific value calculated from the actual hardness that co-occurs with the cadmium exposure. A similar calculation for the short-term WQG reveals a factor of conservatism on the order of 2.7 (Omenica-Peace) to 18.2 (Vancouver Island) if site water has a hardness of 320 mg/L, and a factor of conservatism on the order of 3.9 (Omenica-Peace) to 26.2 (Vancouver Island) if site water has a hardness equal to the upper bound of 455 mg/L. The conservatism of the WQG can also be illustrated through comparison of the hardness-adjusted long-term guideline value to background conditions reported for the Cariboo region at Table 5. The guideline for 50 mg/L hardness as CaCO3 (which is coincidentally the median hardness for the Cariboo region as listed in Table 7) is 0.046 µg/L. The background concentrations for the Cariboo region yield a 75th percentile of 0.02 µg/L dissolved cadmium and 95th percentile of 0.067 µg/L dissolved cadmium; therefore, a significant percentage of background samples from this region (approximately 15%) can be expected to exceed WQG. These would be false positive exceedances.	As noted by the reviewer, the document, "Guidance for the Derivation and Application of Water Quality Objectives in British Columbia" (BCMOE 2013) states that "When there are toxicity-modifying factors (ameliorating or aggravating) present, WQOs must be based on the natural background concentrations of these factors, not levels that have been altered due to human land use (e.g., hardness)". This statement was the basis for extending this guidance to adapting the water quality guideline to site-specific conditions. However, we recognize that the application of water quality objectives and water quality guidelines can be different. Therefore, this statement has been removed from the document. In addition, background concentrations of cadmium in some waterbodies may exceed the long-term average or short-term maximum concentrations. In these situations, site-specific assessments may be required.

Reviewer	Affiliation	Reviewer Comment #	Page	Line	Comments & Questions	Response
G. Larocque	APEGBC, Associate Director, Professional Practice	10	Table 5		There appears to be transcription errors in the statistics presented for dissolved cadmium in the Lower Mainland. The statistics show a value of 0.07 for all percentiles, the mean values, and the maxima. The only way this could occur would be if all 24 measurements had the same concentration.	The evaluation of the background concentrations in British Columbia was significantly reduced due to a lack of data for some regions and water body types. As such, these values have been removed. The concentrations presented in the revised table (Table 4) have been verified.
G. Larocque	APEGBC, Associate Director, Professional Practice	11	General		In terms of document organization, there is a substantial amount of dense technical information in the middle sections of the report, including lengthy discussions of background concentrations and a synopsis of literature reviews for each receptor group. It may be beneficial to move some of this material to Appendices such that the numerical WQG derivation (currently Section 9) is given greater emphasis in the main body of the report.	While this is a reasonable suggestion, the organization of the document has not been revised. The presentation of the material within the main body of the report provides the information required to evaluate the toxicity of cadmium to aquatic life.
G. Larocque	APEGBC, Associate Director, Professional Practice	12	Section 9.3 57-62		In Section 9.3, some of the decision points for developing the hardness model rely heavily on professional judgement; no clear rationale is provided for some of the statements. For example, terms such as "were not markedly different", "provided a robust estimate", "were in reasonable agreement", and "is similar to" are used to convey why the adopted approach is considered appropriate. In some instances it is difficult to determine objectively whether the conclusions are valid (e.g., is a slope of 0.762 similar to 0.939?). Although APEGBC has no objections to the approaches applied in this section, it would be useful to discuss these differences in the context of implications for WQG development.	Text has been revised in certain instances to provide additional rationale. In the case of the comparison of slopes, the range of the confidence intervals was used to determine that the two slopes were similar.
G. Larocque	APEGBC, Associate Director, Professional Practice	13	Section 9.4.3 67-69		Since there is separate discussion of the sensitivity of WQG derivations to slope estimates (i.e. Section 9.4.3), perhaps other sections could be harmonized so that their earlier narratives have a more transparent basis.	While this is a reasonable suggestion, the organization of the document has not been revised. The presentation of the material in sections 9.4.1 and 9.4.2 is to provide greater claritry.
G. Larocque	APEGBC, Associate Director, Professional Practice	14	27 32 Section 9.4 62-71	3 1	There is some inconsistency in the discussion of the importance of the bioaccumulation pathway for cadmium. In various places in the document, the text appears to equivocate on the issue of whether this pathway is sufficiently important to warrant explicit consideration in the WQG derivation. For example, the text at the top of page 27 and page 32 imply that "it is important to consider" this pathway, whereas Section 9.4 appears to exclude this pathway as minor and inconsequential.	Section 6.0 has been revised to provide greater clarity.
G. Larocque	APEGBC, Associate Director, Professional Practice	15	Section 6.0 27-33		The Section 6.0 material is distracting because it presents detailed information for a process that is ultimately excluded from the WQG derivation. The opening sentence of Section 6.0 also requires editing because it is illogical that "tissue chemistry" would be considered to "provide little information about the bioaccumulation" of cadmium.	Section 6.0 has been revised to proivde greater clarity.
G. Larocque	APEGBC, Associate Director, Professional Practice	16	Figure 8		Figure 8 provides an effective means of summarizing a complex data set. Two minor edits would improve on this excellent communication tool. First, the coloured dots could be formatted in a way that the primary data are emphasized (currently the dark dots for secondary studies "leap out" when in fact the primary studies should be emphasized). Use of transparent fill for symbols is also recommended to avoid covering of one result by another overlapping point. Finally, light shading of alternating rows would assist in matching data points to the species names on the left.	As suggested, the primary studies are now represented by dark dots.
Dan Steinke	Urban Systems Ltd.	1			well written and easy to follow. Excellent reference document	Thank you.
Dan Steinke	Urban Systems Ltd.	2	20	5	Is Vancouver Island data similar enough to mainland data to allow for inclusion in the data set? Is Island data included for other BWQ metals guidelines?	For ease of use, the data were grouped into the BC MOE administrative regions. No evaluation of the differences (or lack of) within an administrative region was made. However, the data are available through the BC MOE to do such an analysis.
Dan Steinke	Urban Systems Ltd.	3	24	22	Would like to confirm that calculations made with individual data and not averages.	The distribution of data was described using the station means; however the evaluation of the background concentrations in British Columbia was significantly reduced due to a lack of data for some regions and water body types. However, the range of mean cadmium concentrations by station within each of the administrative regions is presented.
Dan Steinke	Urban Systems Ltd.	4	52	7	Are data presented in Table 8 total Cd levels or dissolved?	Footnotes were added showing which jurisdictions use total cadmium and which jurisdictions use dissolved cadmium for their guidelines.

Reviewer	Affiliation	Reviewer Comment #	Page	Line	Comments & Questions	Response
MABC	MABC	1	General		It should be noted that MABC considers the Species Sensitivity Distribution approach more appropriate for developing water quality guidelines (WQGs) in comparison with the safety factor approach currently employed by BCMoE. That being said, these review comments focus on the derivation of the guideline according to procedures currently employed by BC MoE.	BC's protocol for developing water quality guidelines was used (http://www.env.gov.bc.ca/wat/wq/pdf/wq-derivation.pdf). BC does not use the SSD approach to derive WQGs. The SSD paradigm is not consistent with BC's guiding principles (i.e., protecting the most sensitive species and sensitive life stage indefinitely).
MABC	MABC	2	General		The draft cadmium WQG document is a thorough evaluation of the available toxicity data on cadmium toxicity to aquatic organisms and the authors are complimented on their work; however, we have made a number of recommendations that would enhance and improve the guideline document. MABC supports the need for water quality guidelines to be appropriately conservative and broadly applicable. However, it is equally important that guidelines not be unnecessarily conservative, since this results in "false positive" findings in risk assessments and other environmental investigations, which can result in the mis-direction of industry and government resources, rather than focusing on the mitigation of actual environmental risks. Thus, an appropriate balance is required that results in environmental protection, while providing appropriate guidance so that the guidelines provide an appropriate measure of potential for adverse effect.	Thank you. The most recent scientific data was incorporated into the new Cd WQG. Our guideline is for dissolved Cd, and our revised values have incorporated review comments. This has increased the values for both the short-term and long-term guidelines. The uncertainty factor used for the guidelines has decreased to 2. We feel that we have reached an appropriate balance.
MABC	MABC	3	10	44	It would be worth mentioning here that the CCME guideline has recently been updated.	The text has been revised.
MABC	MABC	4	11	10	Published toxicity tests were not "conducted using dissolved Cd", since in many cases, those studies would have reported total cadmium. Probably better to say that "published toxicity tests were conducted in water types in which cadmium occurs largely in the dissolved form."	The text has been revised to state the intent more explicitly.
MABC	MABC	5	40		This statement on the application of background hardness to calculate water quality guidelines has not been included in previous water quality guidelines that include toxicity-modifying factors, and should be removed. Note that in requiring the use of "background" hardness in determining a WQG for a site, rather than the actual hardness associated with a sample, this would result in an inaccurate assessment of risk posed by the cadmium present at a particular location and time. This approach is not consistent with a "science-based" approach to the use of water quality guidelines, and would result in the identification of apparent risk of toxicity due to cadmium, when none in fact exists, in cases where the water hardness is elevated in relation to background conditions. This approach serves no environmental benefit, since the water quality guideline is designed to be protective at specific combinations of hardness and cadmium, and would result in false positive identification of hazard. It is also unclear how natural fluctuations in water hardness associated with short-term and seasonal conditions, such as rain events and freshet, could be appropriately incorporated in determining actual "background" hardness.	The statements suggesting that background hardness must be used have been removed. Site-specific assessments may be required in situations where conditions have be altered to determine if the WQG is appropriate.
MABC	MABC	6	12	11-13	Note that these bullet points are inconsistent with the use of "background" hardness to calculate the WQG. For example, the exceedance of a WQG based on background hardness will not: identify areas that are necessarily degraded, help statutory decision makers establish safe wastewater discharge limits, and provide accurate information to the public on the state of water quality. Any risk associated with a change in water hardness should be assessed separately from effects of cadmium.	The statements requiring the use of background hardness have been removed.
MABC	MABC	7	17	1	The authors have provided a good rationale here for why the characteristics of the sample (specifically, employing filtration of the sample to determine dissolved cadmium for comparison to the guideline) should be used in assessing the hazard posed by cadmium that is present. Note that this same logic applies to use of the actual hardness of the sample, rather than background hardness.	The statements requiring the use of background hardness have been removed.
MABC	MABC	8	17	5-12	The rationale for the need to monitor both total and dissolved cadmium is unclear. While there may be circumstances in which this is warranted, the current language indicates that it is always required, and this is not necessary in many circumstances. We suggest changing the language here to indicate that "monitoring of both dissolved and total cadmium in the aquatic environment may be useful in some cases because:", etc. Furthermore, we suggest removing the specification "(i.e., biomagnification)", since this has not been indicated for cadmium (as noted by the authors on page 26, line 28).	Agreed. The selection of anlaytes measured should be informed by the study questions. This section has been revised.
MABC	MABC	9	17	27	It would be useful to describe the relationship between total and dissolved cadmium for any samples in the historical data set in which both were measured; if such a comparison was made, it would be helpful is this could be included in the appendices. Much of the historical data set of cadmium measurements will be as "total", and so any guidance that can be provided, such as the relationship between percent dissolved and TSS, hardness, or other factor that is available from this or other datasets would be useful. It would also be useful to describe data for individual stations that have both clear flow and turbid flow data.	While these suggestions are reasonable, these analyses are outside of the scope of the water quality derivation. In addition, the evaluation of the background concentrations in British Columbia was significantly reduced due to a lack of data for some regions and water body types. As such, these values have been removed. The concentrations presented in the revised table (Table 4) have been verified.
MABC	MABC	10	21	8	It is interesting that background cadmium was four times higher under clear flow conditions than under turbid conditions. This is likely an anomaly since there was only one station sampled during turbid conditions; this should be specifically noted.	The evaluation of the background concentrations in British Columbia was significantly reduced due to a lack of data for some regions and water body types. As such, these values have been removed. The concentrations presented in the revised table (Table 4) have been verified.

Reviewer	Affiliation	Reviewer Comment #	Page	Line	Comments & Questions	Response
MABC	MABC	11	23	7	The sections for the other regions discussed 95th percentiles, but this section does not.	The evaluation of the background concentrations in British Columbia was significantly reduced due to a lack of data for some regions and water body types. As such, these values have been removed. The concentrations presented in the revised table (Table 4) have been verified.
MABC	MABC	12	26	19-21	This statement should be supported by literature citations.	Citations have been added.
MABC	MABC	13	27		It should be specified whether the BCFs presented are on a wet or dry weight basis. The same approach should be used for all of the BCFs discussed here.	The recommendation has been incorporated.
MABC	MABC	14	30	3	After presenting the previous BCFs in the hundreds to thousands, a BAF of 0.082 needs some explanation. For example, is this a trophic transfer factor? On page 27, a BAF is identified as including uptake from water and other components from the media, so this number does not make much sense in that context.	The paper from which the 0.082 number comes (van Hattum et al. 1989) considers the BAF to represent accumulation from food alone. A statement has been added to the text explaining this.
MABC	MABC	15	31	19-20	The BAF values reported here are quite low in comparison to the prior studies; some comment on this difference is warranted.	A statement was added that these BAFs might not be as accurate as those reported from other studies because they were calculated using body concentrations estimated from graphs.
MABC	MABC	16	37	4-7	The data presented by Elnabarawy *et al.* (1986) for *Daphnia magna* should be considered "unacceptable". There were no analytical confirmations of test concentrations and, although BCMoE permits this for secondary data in guideline derivation, this should not be permissible for cadmium, in which adverse effects occur in the low ppb range. We also note that the authors of this paper have made errors in calculating their test endpoints. For example, for *D. magna*, the EC16 and MATC were reported as 0.5 and 2.6 µg/L respectively. However, the data shown in Table 3 of that paper show that the 0.25 and 0.75 µg/L Cd concentrations both had reproduction that exceeded the control performance; thus, it does not make sense that the EC16 could be 0.5 µg/L. Furthermore, the MATC from this test should actually be 4.3 µg/L, which is the geometric mean of the NOEC (2.5 µg/L) and LOEC (7.5 µg/L), not 2.6 µg/L as reported by the authors. Based on this, data from this study should be removed from Figures 8 and 9.	The Elnabaraway et al. (1986) study was re-evaluated. Based on the re-evaluation, the IC16, NOEC, LOEC, and MATC were re-calculated after converting the concentrations from CdCl2 to Cd (typographical error in the study). The revised IC16 values (calculated using linear interpolation and smoothed means, when necessary) are plotted in the revised Figures 8 and 9. However, these results were not used as the basis for the long-term WQG nor were they used in the development of the uncertainty factor due to the high uncertainty associated with the study.
MABC	MABC	17	37	4-7	The data presented by Elnabarawy *et al.* (1986) for *Daphnia pulex* should be considered "unacceptable". There were no analytical confirmations of test concentrations and, although BCMoE permits this for secondary data in guideline derivation, this should not be permissible for cadmium, in which adverse effects occur in the low ppb range. We also note that the authors of this paper have made errors in calculating their test endpoints. For example, for *D. pulex*, the EC16 and MATC were reported as 0.2 and 8.6 µg/L respectively. However, the data shown in Table 3 of that paper show that the lowest test concentration of 0.25 µg/L Cd had reproduction that exceeded the control performance; consequently, it does not make sense that an EC16 could be calculated as 0.2 µg/L. Note also that the 2.5 µg/L Cd concentrations, which is more than an order of magnitude higher than the reported EC16, had reproduction that was equivalent to the control performance. Furthermore, the MATC from this test should actually be 13.7 µg/L, which is the geometric mean of the NOEC (7.5 µg/L) and LOEC (25 µg/L), not 8.6 µg/L, as reported by the authors. Finally, an EC50 has been reported as >15.3 µg/L, whereas the highest test concentration was actually 25 µg/L, so the EC50 should be >25 µg/L. Based on this rationale, data from this study should be removed from Figures 8 and 9.	The Elnabaraway et al. (1986) study was re-evaluated. Based on the re-evaluation, the IC16, NOEC, LOEC, and MATC were re-calculated after converting the concentrations from CdCl2 to Cd (typographical error in the study). The revised IC16 values (calculated using linear interpolation and smoothed means, when necessary) are plotted in the revised Figures 8 and 9. However, these results were not used as the basis for the long-term WQG nor were they used in the development of the uncertainty factor due to the high uncertainty associated with the study.
MABC	MABC	18	37	4-7	The data presented by Elnabarawy *et al.* (1986) for *Ceriodaphnia reticulata* (note that the organsism used by these authors, which were obtained from the USEPA lab in Duluth, have subsequently been determined to be *C.dubia*) should be considered "unacceptable". There were no analytical confirmations of test concentrations and, although BCMoE permits this for secondary data in guideline derivation, this should not be permissible for cadmium, in which adverse effects occur in the low ppb range. We also note that the authors of this paper have made errors in calculating their test endpoints. For example, for *C. reticulata*, the MATC should actually be 13.7 µg/L, which is the geometric mean of the NOEC (7.5 µg/L) and the LOEC (25 µg/L), not 8.6 µg/L, as reported by the authors. Furthermore, an EC16 of 0.2 µg/L has been reported; however, this falls outside the range of tested concentrations, and should not be reported. Moreover, the dose-response is noticeably flat across the test concentration range of 0.25 to 7.5 µg/L. It is highly unlikely that an EC 16 of 0.2 µg/L is an accurate representation of the sensitivity of this species to cadmium when there is little or no change in sensitivity at concentrations between 0.25 and 7.5 µg/L Cd (i.e., no change in response to a cadmium concentration that is 37.5 times higher than the calculated EC16). Thus, the reported EC16 is highly suspect, and should not be considered in guideline development. Finally, an EC50 has been reported as >15.3 µg/L, whereas the highest test concentration was actually 25 µg/L, so the EC50 should be > 25 µg/L. Based on this rationale, data from this study should be removed from Figures 8 and 9.	The Elnabaraway et al. (1986) study was re-evaluated. Based on the re-evaluation, the IC16, NOEC, LOEC, and MATC were re-calculated after converting the concentrations from CdCl2 to Cd (typographical error in the study). The revised IC16 values (calculated using linear interpolation and smoothed means, when necessary) are plotted in the revised Figures 8 and 9. However, these results were not used as the basis for the long-term WQG nor were they used in the development of the uncertainty factor due to the high uncertainty associated with the study.
MABC	MABC	19	37	16	As discussed below, the 42 day biomass endpoint is a more appropriate assessment of effects on biomass from the Ingersoll and Kemble (2001) study.	A re-evaluation of the critical studies used to derive both the short-term and long-term WQGs was conducted to support this revision. Based on the re-evaluation, it was determined that the Ingersoll and Kemble (2001) study should be classified as a secondary study. This study is no longer used to derive the WQG.
MABC	MABC	20	37	26 27 30	Confidence intervals are never reported for LOEC values.	The typographical error has been fixed.

Reviewer	Affiliation	Reviewer Comment #	Page	Line	Comments & Questions	Response
MABC	MABC	21	38	10	Confidence intervals are never reported for LOEC values.	The typographical error has been fixed.
MABC	MABC	22	40	13	The EC10 reported by Mebane *et al*. (2008) should be considered with caution, and should not be considered a low effect level. There was no change in sensitivity across a range from 0.16 µg/L (the lowest test concentration) to 2.5 µg/L Cd (the highest test concentration). These result suggest that the control weight was an anomaly, and that the ~4 to 16% reduction in growth observed in the doses were a test artifact rather than being a "real" toxicological response, since there is no evidence of a dose-response relationship. Furthermore, in the initial test conducted by these authors, there was no evidence of adverse effects on growth at concentrations less than 1 µg/L. Finally, a similar effect, involving a minor reduction in weight relative to the control, was observed in a concurrent test performed by these authors using zinc, which appears to have shared the same control as the cadmium test. Thus, it appears likely that the control growth was anomalous in this test. Indeed, the authors concluded that: "For our second Cd test, the statistical LOEC for reduced growth was 0.17 µg/L. However, we think the reduced survival at the highest (2.5 µg/L) Cd exposure is probably the most biologically meaningful overall test effect since it was apparently dependent and the growth reductions were not". Regardless, it should be noted that a 10% effect level is considered by CCME to be a no effect level, and BCMoE bases guidelines on low effect levels from toxicity tests. Based on this rationale, the data point from this study should be removed from Figures 8 and 9.	The EC10 value was removed and replace with the LOEC reported from that study with the caveat that no clear dose-response was apparent.
MABC	MABC	23	42	11	This statement should be supported by literature citations.	Citation has been added.
MABC	MABC	24	43	30	The results from Davies *et al.* (1993), in which hardness was adjusted using magnesium salts should not be hardness-corrected to 50 mg/L hardness and, therefore, not included in Figure 8 or in the guideline derivation.	Agreed. In fact, the Davies *et al.* (1993) study was excluded from the analysis to derive the hardness relationship due to the use of magnesium salts. These results were removed from Figures 6 through 9. The results were not used in the derivation of the WQG.
MABC	MABC	25	49	8-10	There is very little value in citing results from a test in which control mortality was 80%. We would suggest deleting this.	This objective of this study was to investigate the relationship between temperature and toxicity. These "control" responses are cadmium controls, not negative controls. The results of the study remain in the revised document for information, but do not affect the derivation of the WQG.
MABC	MABC	26	52	10-18	The short-term CCME guideline should be included here as well. Also, it should be stated what the guideline is outside of the range of 17 and 280 mg/L hardness. For instance, at hardness values of less than 17, the guideline is 0.04 µg/L.	Additions have been made as suggested.
MABC	MABC	27	53	5	We believe that MOE should consider adding the guideline produced by Mebane (2010).	The intent of Section 8.0 is to provide a summary of relevant water quality guidelines that have been promulgated by other jurisdictions. As the Mebane (2010) guideline has not been adopted by a jurisdiction, it is not relevant for this section.
MABC	MABC	28	58	26	Data for algal growth tests are more appropriately considered as representing a long-term exposure, rather than short term. Although the duration of the test appears "short", the reality is that as a result of high light intensity used in these tests, the test actually reflects a population growth endpoint that would occur over a much longer time period in the real world. Typically, a greater than ten-fold change in cell density is observed in these tests. Furthermore, results presented for algae are cell reproduction (i.e., increase in cell density), and do not incorporate a mortality endpoint, as would typically be used in short-term guideline derivations. Thus, results from these tests do not provide a measure that would be consistent with a severe effect on survival, as is intended (Meays, 2012).	The algal growth data from the 72-h test were reclassifed as long-term endpoints and used as such in evaluating the relationship between water hardness and toxicity as well as for guideline derivation. Note that the pooled slope for the relationship between hardness and toxicity for both the short-term and long-term datasets has changed slightly to reflect this revision.
MABC	MABC	29	59	5-7	The rationale for inclusion of the rainbow trout alevin data is not convincing. In establishing a relationship between a water quality variable and toxicity, the goal should be to minimize other factors that introduce variability, since they will skew the results. In this case, there is a demonstrated difference in sensitivity between alevins and fry, and so in including a single result for alevins, this impacts the relationship in a manner that serves no beneficial purpose. It is appropriate to demonstrate that the established relationships are protective of all species and endpoints, but this is already accomplished in Figure 7. It should also be noted that in introducing variability within individual slopes, this will decrease the sensitivity of the ANCOVA to detect significant differences among slopes.	The data used to generate the hardness-toxicity relationship for rainbow trout consist of effect concentrations from multiple studies and life-stages to ensure that an adequate amount of data were available for the evaluation. This section was revised to more clearly state the data limitations for evaluating the relationship between hardness and toxicity for rainbow trout.
MABC	MABC	30	60	4	If would be best if the slopes could be determined on the basis of 50% effect levels from these tests, rather than the MATC values, since this provides the most accurate toxicity test endpoints from the tests. Since the purpose here is just to evaluate the effect of a water quality variable on the toxicological response, the 50% effect level will provide the most robust assessment. Endpoints derived from hypothesis tests (i.e., LOEC, NOEC and MATC values) and low point estimates like IC10 values have inherent variability. Consequently, MATCs and low effect thresholds do not minimize variability, as is suggested here.	It is agreed that endpoints derived from hypothesis tests would not minimize the variability. In addition, while LC/IC/EC_{50} values would ideally be used in this context, these effects concentrations were not readily available for this analysis. This section has been revised for clarity and accuracy.

Reviewer	Affiliation	Reviewer Comment #	Page	Line	Comments & Questions	Response
MABC	MABC	31	61	23	Slope estimates from CCME should be compared here as well.	At the time this report was drafted, the CCME guideline was still in draft. The revised version has been updated with the information from CCME 2014.
MABC	MABC	32	62	3	Slope estimates from CCME should be compared here as well.	At the time this report was drafted, the CCME guideline was still in draft. The revised version has been updated with the information from CCME 2014.
MABC	MABC	33	62	35	It should be mentioned here that results of dietary investigations have not generally indicated that cadmium accumulation between trophic levels is significant and that biomagnification does not occur.	The document has been revised with the suggested language.
MABC	MABC	34	63-64		Cadmium toxicity has been extensively studied and the authors have done well in summarizing the available information. Primary data were identified for 22 studies and secondary data were identified from 4 studies, for a total of 106 LC50 or EC50 estimates, including 26 LC50 values for the most sensitive species. This is a significant body of information on the sensitivity of *Oncorhynchus mykiss* to cadmium in short-term exposures. The amount of information exceeds that available for other recently derived guidelines by a considerable margin, and a two-fold safety factor appears to be all that is warranted on that basis. This would result in a short-term guideline of 0.289 µg/L at a hardness level of 50 mg/L. It should be noted that for their guideline, the CCME determined a short-term WQG of 1 µg/L Cd at 50 mg/L hardness, and the suggested revised BCMoE guideline is still more than three times more conservative than the CCME guideline.	BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. A re-evaluation of the critical studies used to derive the short-term WQGs was conducted. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate as suggested. Note that the CCME short-term benchmark is not meant to be a protective number and therefore is not directly comparable to BC's short-term WQG.
MABC	MABC	35	64	2	The approach taken in determining the safety factor to be applied in calculating the short-term guideline does not appear to be consistent with historical practice, or recent guidance provided by MoE (Meays 2012). A 3.5-fold safety factor was selected on the basis of the ratio between LC50 and LC10 estimates for toxicity tests conducted using rainbow trout, which produced a ratio of between 1.8 and 3.1. It appears that the 3.5-fold safety factor was selected because it exceeds this range; additional rationale for selection of this safety factor should be provided. It should be noted that the results cited here are six measures of the same endpoint, conducted by the same authors, and the actual ratio between the LC50 and LC10 for trout is best calculated as the geometric mean of the results from the six tests. None of the individual tests provides the "correct" measure for sensitivity to cadmium, or the slope of the dose-response curve. In fact, the information collectively provide the most accurate assessment of these factors. Thus, on this basis, the ratio of the LC50 to the LC10 for rainbow trout from these six tests is 1.64, and to protect against a 10% effect on survival of rainbow trout, a two-fold safety factor is more than sufficient to accommodate that. Comparing the LC50 to the LC10 is an interesting exercise, although it should be noted that the short-term WQG is not meant to protect against effects on 10% of organisms. Meays (2012) indicates that "Short-term maximum guidelines are intended to protect against any severe effects such as lethality (e.g., LC50) or equivalent (e.g., EC50) to the most sensitive species over a defined short-term exposure period (i.e., 96 hours)."	BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. A re-evaluation of the critical studies used to derive the short-term WQGs was conducted. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate.
MABC	MABC	36	64	18	Short-term guidelines are not designed to protect against behavioural effects; they are meant to protect against severe effects on survival.	This statement is provided for context only.
MABC	MABC	37	65-66		The draft cadmium guideline is based on application of a safety factor to a 28-day IC25 of 0.51 µg/L for *Hyalella azteca* from Ingersoll and Kemble (2001). The 28-day IC25 of 0.51 ug/L for biomass should not be considered to be a reliable test endpoint from this study. Of specific note is that the NOEC and LOEC for this test endpoint were 1.9 and 3.2 µg/L, respectively, indicating that in order to detect a statistically-significant difference in biomass relative to the control, a concentration that was more than six times higher than the reported IC25 would be necessary. Thus, there is very little confidence in the accuracy of this point estimate. Interestingly, Mebane (2010) re-analyzed the raw data from Ingersoll and Kimble (2001), and reported a 28-day EC20 for biomass of 1.7 µg/L using logistic regression. Confidence limits from this analysis were 1.1 - 2.5 µg/L. Fortunately, the test described above was actually a 42-day test, with the 28-day data being an interim measure. Thus, the data from test termination at 42 days provides a more appropriate effect measure from this test, since it encompasses the entire 28-day period, as well as an additional 14 days of exposure. At the end of the 42-day period, eight replicates were terminated, compared with only four replicates at day 28, providing a more robust dataset with which to calculate point estimates. The IC25 at the end of this time period was 1.9 µg/L, which, interestingly, is similar to the recalculated 28-day EC20 of 1.7 µg/L reported by Mebane (2010). This appears to be a more appropriate effect level for biomass, although even this value also falls below the NOEC of 3.2 µg/L. In fact, at the end of the 42-day exposure period, there were no statistically-significant differences detected in biomass in any of the test concentrations, up to and including the highest test concentration of 3.2 µg/L. Thus, establishing a benchmark of 0.17 µg/L Cd (at the hardness of this test) on the basis of effect levels from this test at this hardness is unnecessarily conservative. Based on this rationale, data for the 28-day IC25 of 0.51 µg/L should be removed from Figures 8 and 9 and excluded from consideration in the guideline.	The Ingersoll and Kemble (2001) study was re-evaluated. Based on the re-evaluation, this study was given a secondary classification and not used in the guideline derivation. The reported IC_{20} of 0.253 µg/L (normalized to 50 mg/L $CaCO_3$) reported in Chadwick Ecological Consultants, Inc. 2004 was used as the basis for the long-term guideline.
MABC	MABC	38	66		A three-fold safety factor was applied to the IC25 of 0.51 ug/L for *Hyalella* to derive the guideline. This approach resulted in a proposed guideline value that is 18.8 times lower than the concentration of cadmium that actually yielded a statistically-significant difference in biomass at 28 days relative to the control. In other words, a statistically-significant adverse effect on *Hyalella* was only observed at a concentration that was almost 20 times higher than the proposed guideline. This is an unnecessarily large safety margin to employ in a guideline calculation, particularly considering there are other sensitive endpoints for this species from Chadwick Ecological Consultants (2004).	BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. A re-evaluation of the critical studies used to derive the long-term WQGs was conducted. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate.

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MABC	MABC	39	66	9	As discussed above, the EC16 effect levels reported by Elnabarawy *et al.* (1986) have been incorrectly reported by those authors, and fall well below concentrations that were actually associated with adverse effects in those tests. These test endpoints should be considered unacceptable, and removed from the discussion here. Note that the species used was identified by the authors as *Ceriodaphnia reticulata* and not *C. dubia* as is indicated here in the Draft WQG. However, it likely was actually *C. dubia* that was tested, since it was obtained from the USEPA lab in Duluth, and their culture was re-identified as *C. dubia* rather than *C. reticulata* in the mid-1980s.	The Elnabaraway et al. (1986) study was re-evaluated. Based on the re-evaluation, the IC16, NOEC, LOEC, and MATC were re-calculated after converting the concentrations from CdCl2 to Cd (typographical error in the study). The revised IC16 values (calculated using linear interpolation and smoothed means, when necessary) are plotted in the revised Figures 8 and 9. However, these results were not used as the basis for the long-term WQG nor were they used in the development of the uncertainty factor due to the high uncertainty associated with the study. *C. dubia* was changed to *C. reticulata* .
MABC	MABC	40	66		After excluding the 28-day IC25 for biomass from Ingersoll and Kemble (2001), the data from Elnabarawy *et al.* (1986), and the low level effect on trout growth reported by Mebane *et al.* (2008) for the reasons identified above, the most sensitive low effect threshold for cadmium is for biomass of *Hyalella,* reported by Chadwick Ecological Consultants (2004). Two tests reported by these authors produced IC20 estimates of 0.247 and 0.324 µg/L, after correcting to a hardness level of 50 mg/L. An appropriately conservative WQG for cadmium could be calculated by dividing the lower of these values by a safety factor of two, resulting in a guideline value of 0.124 ug/L at a hardness of 50 mg/L. The only values that were reported in the draft WQG as primary or secondary and that fell below this were two EC16 values from Elnabarawy *et al.* (1986) which, as noted above, were incorrect and should be excluded. The figure provided here shows the proposed alternate guideline along with the low effect levels that were reported in the draft guideline. The data points that have been identified here as "excluded" are: the incorrectly-calculated EC16 values from Elnabarawy *et al.* (1986); the IC25 of 0.51µ/L Cd for *Hyalella* from Ingersoll and Kemble (2001); and the anomalous growth response observed by Mebane *et al.* (2008). The proposed revised guideline is calculated as e^(0.762 x ln(hardness) - 0.5072).	The Ingersoll and Kemble (2001) study was re-evaluated. Based on the re-evaluation, this study was given a secondary classification and not used in the guideline derivation. The reported IC20 of 0.253 µg/L (normalized to 50 mg/L CaCO3) reported in Chadwick Ecological Consultants, Inc. (2004) was used as the basis for the long-term guideline. In addition, a re-evaluation of the critical studies used to derive the long-term WQG was conducted to support this revision. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate for application to the long-term WQG. The revised long-term guideline is 0.127 µg/L (normalized to 50 mg/L CaCO3).
MABC	MABC	41	67	1	As mentioned above, it needs to be clear what the WQG is when the hardness is less than 17, and/or greater than 285 mg/L.	Guidance on the determination of the guideline for waters with hardness outside this range has been added to sections 9.4.1 and 9.4.2.
MABC	MABC	42	67	6	The toxicity test endpoint reported by Ingersoll and Kemble (2001) was not calculated using a regression-based approach, as is indicated here. In fact, it was calculated by linear interpolation, which can result in poor estimates of low effect levels in cases where there is a high degree of variability in the dataset, as appears to be the case here. Note that Mebane (2010) re-analyzed these data using a regression-based approach, and derived a higher estimate of the IC20 of 1.7 µg/L.	The Ingersoll and Kemble (2001) study was re-evaluated. Based on the re-evaluation, this study was given a secondary classification and not used to derive the guideline value.
MABC	MABC	43	67	17	The additional rationale provided here to support the uncertainty factor of 3 is unnecessary. The fact that other reported values are available that are higher than the endpoint selected should be used to help establish the uncertainty, not the results from an individual test. As noted above, a three-fold safety factor below an effect level of 0.51 µg/L produces an estimate of 0.17 µg/L Cd, which is almost 20 times lower than the LOEC for this endpoint.	BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. A re-evaluation of the critical studies used to derive the long-term WQG was conducted. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate.
MABC	MABC	44	69	4	After "…multiple contaminants", it would be appropriate to add "for toxicants that are expected to act by the same mode of toxicity".	The suggested language has been added.
MABC	MABC	45	69	16	The specifications for what is constituted by atypical pH is not necessary and should be removed.	The specifications have been removed.
MABC	MABC	46	70	15	It is not clear why the role of "natural geologic processes" is necessary to establish whether the guideline is appropriate or not. Guidelines are generally based on toxicity tests that have been conducted under water quality characteristics of various laboratories' water sources, which may or may not reflect geologic processes. Indeed, standard ASTM water reflects an unusual blend of ions compared with most natural geologies. Conversely, anthropogenic sources of hardness, whether from mining operations, wastewater discharges, or otherwise, are generally consistent with natural geologic processes in terms of ratios of major ions. We would suggest that this section be changed to remove the reference to natural geologic processes and anthropogenic sources and, rather, focus the discussion on ratios of ions that are not consistent with waters that have been historically used in toxicity testing.	This section has been revised to focus on ion ratios.
MABC	MABC	47	70	17-21	It is not clear why "elevated levels of organic matter, elevated levels of total dissolved solids (TDS), atypical pH, or saltwater intrusion" have been identified here as instances for which the WQG may or may not be protective. In general, decreased cadmium toxicity would be expected under most of these scenarios, so citations should be provided if there are cases for which increased cadmium toxicity has in fact been shown, as is implied. Alternatively, this sentence should be removed and replaced with a general sentence, such as "Furthermore, the recommended WQGs for cadmium may or may not be protective of all freshwater species in cases where additional stressors may be present". It should be noted, however, that the safety factor is designed in part for this purpose.	The sentence was revised to state that the WQG may not be suitable, to remove the implication that increased toxicity would be expected.

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MABC	MABC	48	Appendix tables		Data for *Daphnia pulex* presented by Chadwick Consultants should be considered "unacceptable", and not "primary". The test duration for this test was 21 days, and the controls failed to meet test acceptability criteria at day 21. It is not appropriate to determine on a *post-hoc* basis that data from day 18 is appropriate to use, when day 21 was not, since there was a stress on the test organisms that caused the test to fail control acceptance criteria. It should be noted, as well, that the IC20 values that were reported for *D. pulex* for survival and reproduction (1.45 and 2.17 µg/L, respectively) were approximately an order of magnitude lower than the LOEC, which was higher than the highest test concentration (i.e., >14.6 µg/L). Consequently, there is very little confidence in these estimates, or indeed whether there was actually an effect observed on reproduction in this test at all. Based on this rationale, data from this test should be removed from Figures 8 and 9.	The *D. pulex* data from this study have been re-classified as unacceptable. These data were not explicitly used in the derivation of the WQG.
MABC	MABC	49	Overall		Toxicity tests are currently being conducted on behalf of an MABC member company which will add substantively to the available dataset on sensitivity of key species to cadmium, including those species for which we have indicated that data should be excluded. In particular, data are expected for *Hyalella azteca*, *Ceriodaphnia dubia*, *Daphnia magna, Daphnia pulex*, and *Oncorhynchus mykiss*. The results will be available in early August for *C. dubia*, with the remaining data becoming available this fall, and MABC would strongly recommend that BCMoE consider them, and the extent to which they affect the interpretation of the guideline and the other comments made here, prior to finalizing the guideline.	The data will be considered once they are available. In the event that further amendment is warranted, it will be considered.
MABC	MABC	50	10	42	MOE or MoE - should be consistent throughout	BC MOE is now used throughout.
MABC	MABC	51	11	34	They were "included", since they have just been referenced, but not updated.	The suggested edit has been incorporated.
MABC	MABC	52	16	30	Suggest adding "suspended" in front of sediments	The suggested edit has been incorporated.
MABC	MABC	53	21	8	Add "all" before samples	This sentence was deleted from the revised version due to a complete re-working of Section 4.0.
MABC	MABC	54	21	11	Is this for all samples collected?	This sentence was deleted from the revised version due to a complete re-working of Section 4.0.
MABC	MABC	55	27	18	Perhaps excretion rather than exclusion	The suggested edit has been incorporated.
MABC	MABC	56	28	4	Perhaps resulted in, rather than permitted	The suggested edit has been incorporated.
MABC	MABC	57	30	30	Has this species name already been identified in full in the document?	The species is now identified in full.
MABC	MABC	58	31	6	Are these BAFs? Or BCFs?	These are BCFs. This has been clarified in the text.
MABC	MABC	59	34	1-3	The last sentence appears a bit out of place.	This sentence was incorporated into Section 6.0
MABC	MABC	60	34	31	Has this species name already been identified in full I the document? Also, recommend providing a reference to its new name, *Pseudokirchneriella subcapitata*.	The species is now identified in full.
MABC	MABC	61	34	30-32	This sentence could use some editing.	This sentence has been revised.
MABC	MABC	62	35	17-21	This might be better in Section 7.1	This information was retained in this section as it related to invertebrates.
MABC	MABC	63	36	2	Suggest you add "invertebrate" before species, since *Daphnia* actually is not among the most sensitive species, which are dominated by fish	The suggested edit has been incorporated.
MABC	MABC	64	36	9 11 14	Suggest you use conducted or performed, rather than run	The suggested edit has been incorporated.
MABC	MABC	65	36	26	Suggest adding its new name, *C. dilutus*	The suggested edit has been incorporated.
Angela Waterman	MABC (Moe_2014_08-12_Cadmium WQG)	1			MABC supports the need for water quality guidelines (WaG) to be appropriately conservative and broadly applicable. However, it is equally important that guidelines not be unnecessarily conservative, since this results in "false positive" findings in risk assessments and other environmental investigations, which can result in the misdirection of industry and government resources, rather than focusing on the mitigation of actual environmental rísks. Thus, an appropriate balance is required that results in environmental protection, while providing appropriate guidance so that the guidelines provide an appropriate measure of potential for adverse effect.	BC's protocol for developing water quality guidelines was used to develop the cadmium WQG (http://www.env.gov.bc.ca/wat/wq/pdf/wq-derivation.pdf).

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Angela Waterman	MABC	2			MABC acknowledges the considerable effort that has gone into development of the guideline and commends the MoE and the authors on their efforts. A review of some of the key studies for the most sensitive species has, however, identified scientificallydefensible rationale for exclusion of data from studies in which errors were identified (Elnabarawy et ol., 1986), and where anomalous test responses have been discovered (i.e., Ingersoll and Kemble 2001, and Mebane et o1.,20081.	A re-evaluation of the critical studies used to derive both the short-term and long-term water quality guidelines was conducted. As a result, both the short-term and long-term guidelines have been revised.
Angela Waterman	MABC	3			The MoE draft guideline for Cadmium is very low in relation to guidelines developed in other jurisdictions. The hardness-dependent Cadmium guidelines derived by BC, CCME, USEPA, and the State of Idaho are markedly different (Figure 1 and 2), despite being derived from largely the same toxicity literature. Some of the differences among guidelines are due to: - different methods of derivation (SSDI vs. lowest endpoint * safety factor); - different hardness-dependent slopes; and, - different endpoints used from the same study (e.9., LOEC, MATC, or lC25)	BC's protocol for developing water quality guidelines was used (http://www.env.gov.bc.ca/wat/wq/pdf/wq-derivation.pdf)
Angela Waterman	MABC	4			The quantity and qualíty of available information for Cadmium in the literature (and other sources) indicates that a minimum two-fold safety factor is appropriate for both maximum and average guidelines. This is in contrast to the 3-fold safety factor applied to the Hyolella oztecs data to derive the draft guideline, and the l-8.8-fold margin between the proposed guideline and the test concentration where effects that were actually detected (statistically) in that test (see note #66 on comment table; attached). This is an unnecessarily large safety margin to employ in a guideline calculation.	BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. A re-evaluation of the critical studies used to derive both the short-term and long-term WQGs was conducted. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate for both the short-term and long-term WQGs as suggested.
Angela Waterman	MABC	5	Figure 3		lf the guideline is re-calculated in a manner that still uses the MoE safety factor approach, but safetv factor. the following guideline results (see Figure 3 below). This refined guideline is protective of all species and life stages, with a two-fold or greater safety margin for all individual acceptable test results.	BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. A re-evaluation of the critical studies used to derive both the short-term and long-term WQGs was conducted. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate for both the short-term and long-term WQGs as suggested.
Angela Waterman	MABC	6			Despite the above, MABC would like to reiterate its position that an SSD reflects the current state-of-the-science with respect to water quality guideline development (see recent report submitted to MoE by MABC; B. Zajdlik & Associates,2OL4l, and should be used to derive BC WQGs going forward.	BC's protocol for developing water quality guidelines was used (http://www.env.gov.bc.ca/wat/wq/pdf/wq-derivation.pdf). BC does not use the SSD approach to derive WQGs. The SSD paradigm is not consistent with BC's guiding principles (i.e., protecting the most sensitive species and sensitive life stage indefinitely).
Angela Waterman	MABC	7			With respect to the finalization of the Cadmium water quality guidelines, MABC would request additional dialogue to address the above-mentioned issues; we propose this as an agenda item for our upcoming Communication Forum meeting this fall.	Noted.
Teck Resources	Teck Resources	1	12	4-14	The Introduction includes a list of bullets that summarize the goals of provincial water quality guidelines and its applicability to the draft cadmium document. In general most of the bullets begin with the language "to provide a basis for… " Inclusion of this language is critical and should be added to Line 11 which presently reads "to identify areas with degraded conditions and need remediation; ". Given that it is MOE policy to apply an "uncertainty factor" (commonly referred to as a safety factor) to water quality guidelines, an exceedance of the guideline does not by default indicate, nor should it even suggest, that an unacceptable risk or "degraded conditions" exist so as to require "remediation". The water quality guideline is intended to be used as a screening tool to identify if additional investigation/data evaluation are warranted and it is not intended to differentiate and identify unacceptable risks, degraded conditions, or the need for remediation. Therefore, it is suggested that Line 11 be modified to read: "to provide the basis for identifying areas where degraded conditions may exist and warrant further evaluation;". In addition, it is recommended that language be added in the Introduction clearly acknowledging that exceedance of the guideline does not imply that an unacceptable risk exists or that environmental conditions have been degraded; but that additional environmental monitoring may be warranted and/or recommended. Without such an acknowledgement many readers of the document will infer that cadmium concentrations in excess of the guideline represents an environmental and/or human health risk. Such a misinterpretation of the guideline only serves to increase confusion and uncertainty in communications with agencies, industry, and the public.	Text has been revised with suggested langauge.

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Teck Resources	Teck Resources	2	13	8-27	We recognize MOE's policy of applying an "uncertainty factor " in the development of water quality guidelines and that this is a policy decision and therefore this should be acknowledged and communicated as such. It should not be communicated solely as a technical science-based decision. Therefore, it is recommend that a "Foreword" section be added to the document that clearly outlines the procedures and policies used to develop water quality guidelines; informing readers/users that science is used to identify effect concentrations for a wide range of sensitive assessment endpoints (e.g., survival, growth, and reproduction) and then is dividing by an "uncertainty factor" that is based on MOE policy that at the time of writing ranges from 2 to 10. Reference: Meays, C. (2012). Derivation of Water Quality Guidelines to Protect Aquatic Life in British Columbia. Water Protection and Sustainability Branch, Environmental Sustainability and Strategic Policy Division, Ministry of Environment. January 2012.	The reference for the guidance is provided in the document. It is noted in the introduction section that the use of an uncertainty factor is a policy decision; however scientific judgement is used when determining the value.
Teck Resources	Teck Resources	3	16	14-25	The first paragraph of this section is not necessary. Should it be retained, it is recommended that it be edited to remove any subjectivity. Specifically, Line #19 the text "... and are therefore less appropriate for determining a suite of analytes in an environmental sample. " It is recommended that the paragraph be edited to read: "A variety of instruments and associated methods are used to measure cadmium in environmental samples (e.g., water samples). Methods include: flame atomic absorption spectrometry (FAAS; detection limit around 1.0 µg/L), graphite furnace atomic absorption spectrometry (GFAAS; detection limit around 0.01 µg/L), inductively coupled plasma atomic emission spectrometry (ICP-AES; detection limits 0.1 and 1.0 µg/L), and inductively coupled plasma mass spectrometry (ICP-MS; detection limits of 0.001 to 0.01 µg/L) (Thermo Elemental 2001)."	The paragraph has been revised to remove the subjectivity.
Teck Resources	Teck Resources	4	17	1-12	Text within this portion of the document is unclear. As presently written, it implies that the dissolved fraction cannot be used to evaluate potential risks to aquatic life through direct toxicity. Typically, aqueous exposures are used to provide a direct means to evaluate the potential for toxicity. It is assumed that what the author(s) were trying to communicate is that aqueous exposure is one form of exposure and depending on the receptor of interest and/or site-specific conditions, other medium may be important in evaluating the potential for unacceptable risks. Therefore practitioners/users may wish to consider collecting information above and beyond dissolved cadmium concentrations. Although accurate, given that the document is a water quality guideline that addresses and evaluates waterborne cadmium exposures, it is inappropriate to suggest what other measures should or should not be evaluated to assess potentially unacceptable risks.	The paragraph has been revised to provide better clarity.
Teck Resources	Teck Resources	5	17	1-12	The rationale provided in support of measuring the total fraction in the water column is lacking. Specifically, it is unclear how the total fraction would be used to "protect against contamination of bottom sediments..." We are not aware of a recognized relationship that equates the total fraction in the water column into a sediment concentration. Unless one can be provided this is not a sufficient reason to suggest that measuring the total fraction is required.	This section has been revised to provide better clarity.
Teck Resources	Teck Resources	6	17	1-12	The second bullet (line # 11-12) in relation to cadmium is not applicable. Cadmium does not biomagnify (refer to page 33 of the draft guideline document) as suggested. This bullet should be deleted. In consideration of the above-mentioned, it is recommended that the text be modified as follows: While measurements of dissolved metals in water may provide a more effective basis for evaluating the potential effects of metals on fish and aquatic life, such measurements may not provide comprehensive data for evaluating risks to aquatic life associated with exposure to metals.	This bullet has been revised to state "WQGs based on the dissolved fraction are not designed to protect against accumulation through diet".
Teck Resources	Teck Resources	7	17	18-21	This section of the guideline is intended to discuss "Environmental Concentrations of Cadmium in British Columbia Waters" and yet within Line #19 it is referencing a document that was specifically developed for waters within the United States. As noted within Section 2.1 of ATSDR (2012), discussions contained therein are geared toward "background and environmental exposures to cadmium in the United States". Therefore it is recommended that the document consider other more relevant references such as the 2014 CCME cadmium guideline (2014), where the Environmental Water Quality Database indicated that freshwater cadmium concentrations in British Columbia ranged from <0.1 to 8.6 µg/L.	The information collected from Environment Canada, BC MOE, and the private sector were all used to provide general estimates the background concentrations of cadmium in BC. The evaluation of the background concentrations in British Columbia was significantly reduced due to a lack of data for some regions and water body types. However, the range of mean cadmium concentrations by station within each of the administrative regions is presented.
Teck Resources	Teck Resources	8	18	14-23	To estimate background concentrations within the province it would appear that the dataset was divided into lotic and lentic data sets. The rationale for this distinction however has not been provided, nor is a technical reason apparent. Additional explanation is warranted. To the best of our knowledge the potential for effects due to cadmium or mode of action do not differ between lotic and lentic environments. A cadmium water quality guideline should apply to all freshwaters regardless of their hydraulic retention time. Not only do the technical reasons for this distinction require further elaboration, but making such a data handling decision has the potential to limit the number of samples being analyzed in the calculation of background concentrations. Depending on the number of available samples, such a data handling decision may not allow for a statistically robust evaluation For instance, the data presented within the tables results in a sample size of 3 in some instances. Establishing background concentrations on three sample lacks sufficient rigor.	The evaluation of the background concentrations in British Columbia was significantly reduced due to a lack of data for some regions and water body types. However, the range of mean cadmium concentrations by station within each of the administrative regions is presented.

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Teck Resources	Teck Resources	9	18	16-23	The calculation of background conditions incorporates a data screening step of distinguishing turbid and clear flow conditions. It is acknowledged that during high-flow conditions the potential for increased suspended sediment loads occurs and is a natural occurrence. It is unclear however what the intent of this distinction is within the draft document and if or how such information is to be applied by practitioners. As a result of the data screening step three categories of background conditions are identified within the draft document. They include: 1) mean total and dissolved concentrations by station for all lotic and lentic station consisting of all collected samples; 2) mean total and dissolved concentrations by station for lotic stations consisting of samples collected during clear flow conditions (i.e., TSS <25 mg/L or turbidity <8 NTU); and 3) mean total and dissolved concentrations by station for lotic stations consisting of samples collected during turbid flow conditions (i.e., TSS >25 mg/L or turbidity >8 NTU). Given that the draft guideline is based on the dissolved fraction and is only dependent on water hardness, it is unclear what the intent of these calculations/distinctions are and how are they to be considered within the context of the draft guideline and/or its intended application.	The information on background conditions is for providing context only. These data do not obviate the need for site-specific background characterization. That being said, the evaluation of the background concentrations in British Columbia was significantly reduced due to a lack of data for some regions and water body types. However, the range of mean cadmium concentrations by station within each of the administrative regions is presented.
Teck Resources	Teck Resources	10	19	1	It is stated that regression on order statistics (ROS) was used to help interpret non-detected samples. We appreciate and encourage the use of such techniques so as to maximize the available data sets. Given that other such techniques are also available, it would be greatly appreciated if supporting calculations and rationale for this approach as opposed to other techniques such as maximum likelihood estimation (MLE) method be provided.	BC MOE has provided guidance for the use of various statistical techniques to deal with non-detect data (Huston and Juarez-Colunga 2009). While MLE is a robust approach for dealing with non-detect data in situations where a large number of samples are present (n > 50), ROS provides a robust method for developing summary statistics in situations where a smaller number of samples are present (i.e., n < 50).
Teck Resources	Teck Resources	11	19	17-19	The third bullet reads: "Mean total and dissolved concentrations by station for lotic stations consisting of samples collected during turbid flow conditions (i.e., TSS <25 mg/L or turbidity <8 NTU)." There is a typographical error in the above statement for as defined on page 18, line number 19, turbid flow conditions as defined by Caux et al. (1997) is when TSS >25 mg/L or turbidity >8 NTU. Therefore the third bullet should read as follows: Mean total and dissolved concentrations by station for lotic stations consisting of samples collected during turbid flow conditions (i.e., TSS >25 mg/L or turbidity >8 NTU).	The evaluation of the background concentrations in British Columbia was significantly reduced due to a lack of data for some regions and water body types. However, the range of mean cadmium concentrations by station within each of the administrative regions is presented. This bullet is no longer included in the revised document.
Teck Resources	Teck Resources	12	19	32	It is recommended that an Appendix be added that clearly outlines and presents how background concentrations were determined. Based on the description of data handling procedures and using the data provided within the document, we were not able to replicate the background concentrations reported within the draft document. An example of the differences in calculated background concentrations is provided for "Vancouver Island" and Kootenay regions, see below plots. As indicated by the data plots, the calculated 95th percentile using ROS is greater than the concentrations reported within the draft guideline. In addition to these discrepancies, it is unclear why other background data sets such as those made available from third parties (e.g., Seabridge Gold, Xstrata Coal, Cardero Coal, and CKD Mines) were not considered. Typically these data sets were far more robust and yet were not selected for consideration. Additional rationale for excluding these data sets is required.	The evaluation of the background concentrations in British Columbia was significantly reduced due to a lack of data for some regions and water body types. However, the range of mean cadmium concentrations by station within each of the administrative regions is presented. This bullet is no longer included in the revised document.
Teck Resources	Teck Resources	13	25	32	The last sentence of this page as written equates organically-rich waters with polluted waters. Specifically it reads: "Additionally, in organic-rich or polluted waters, cadmium readily adsorbs to humic acids and other organic substances (USEPA 1979)." A review of USEPA (1997) did not identify where this was stated, it would be greatly appreciated if a page number could be identified. Alternatively, perhaps the point of this is simply that cadmium readily adsorbs onto organic substances; and as such, a suggestion to text modification could be: Additionally, in organically-rich waters, cadmium readily adsorbs to humic acids and other organic substances (USEPA 1979).	This sentence was revised as suggested.
Teck Resources	Teck Resources	14	26	2-4	Reference to the residence time of cadmium in an aquatic system is unclear. If the reference is intended to be associated with a certain body of water and its hydraulic residence time, it is unclear how this information helps inform the draft guideline or what users/readers of the guideline are intended to do with such information. Additional clarity is required or the sentence simply deleted.	Agreed. This sentence was removed.
Teck Resources	Teck Resources	15	26	15-16	The last sentence of this paragraph presently reads "In addition, cadmium may disassociate from sediments under certain conditions (USEPA 1979)." Unless the aforementioned conditions are described it is unclear as to the purposes of this sentence and it is recommended that it be deleted. Depending on conditions (e.g., pH, oxidative-reduction potential etc.) many metals can disassociate from sediments.	This sentence was revised to include "as well as other metals".

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Teck Resources	Teck Resources	16	27	Section 6	Section 6.0 of the draft guideline is confusing as to its overall message. At the beginning of the section it implies that field collected data (e.g., concentrations as determined in water, sediment, and tissues) simply provide contaminant concentrations but that bioconcentration factors (BCFs) and bioaccumulation factors (BCFs) are of importance. In the case of cadmium, this is not true and the language should be modified to ensure that subjectivity is removed. The relatively simply measure of BCFs is often a tool employed within risk assessments, but has been discouraged for metals in general (Fairbrother et al., 2007; exceptions being organo-metals); and as is the case for cadmium, simply cannot be applied (McGeer et al. 2003). As a result, it is unclear based on the current structure of this section as to what is being suggested or the purpose of the section. Near the end of the section it begins to identify an important message, in that existing scientific literature does not support that cadmium biomagnifies, but the remaining section is unclear. The section fails to acknowledge that, as with many metals, bioaccumulation in and of itself does not mean that deleterious effects will occur. If the purpose of this section is to identify for practitioners that when considering potential adverse effects associated with cadmium within the aquatic environment in general, direct exposure via water is of primary importance, with exposures from sediments or tissues being of lesser importance, this does not come across. The section should be restructured to better communicate the hierarchy in lines of evidence in considering the potential effects of cadmium in relation to the draft guideline. References: Fairbrother, A., R. Wenstel, K. Sappington, and W. Wood. 2007. Framework for metals risk assessment. Ecotoxicol. Environ. Saf. 68, 145-227. McGeer, J.C., K.V. Brix., J.M. Skeaff, D.K. DeForest, S.L. Brigham, W.J. Adams, and A. Green. 2003. Inverse relationship between bioconcentration factor and exposure concentration for metals: implications for hazard assessment of metals in the aquatic environment. Environ., Toxicol. Chem. 22, 1017-1037.	A statement was added at the beginning of Section 6.0 stating that BCFs and BAFs are not important for metals, or for cadmium in particular. The purpose of the section (to provide information on the studies that have been conducted to investigate the potential for bioconcentration and bioaccumulation of cadmium) was explicitly stated. At the end of the section a statement was added stating that direct exposure from water is the primary pathway for cadmium toxicity.
Teck Resources	Teck Resources	17	26	4-6	Insert the word "of" between "each" and "the". Presently the sentence reads: "However, in the same study, the authors reported that D. magna exhibited a wide range of sensitivity to cadmium, depending on the genetic strain used in each the eight tests." It should be modified to read: However, in the same study, the authors reported that D. magna exhibited a wide range of sensitivity to cadmium, depending on the genetic strain used in each of the eight tests.	Edits have been incorporated as suggested.
Teck Resources	Teck Resources	18	51	24-26	The statement that "…there is currently no short-term and/or long-term BLM for cadmium that could be applied to evaluate toxicological data from multiple species for use in developing site-specific WQGs under a variety of water-quality conditions. " is not entirely accurate. First, it is unclear what is meant by "site-specific WQGs ". To the best of our knowledge, water quality guidelines (WQGs) are not site-specific but rather and as noted within the Executive Summary and Section 1.0 of the draft guideline, are province-wide ambient water quality guidelines for surface waters. It is unclear if the reference to site-specificity was intended to refer to Science Based Environmental Benchmarks, Water Quality Objectives (WQOs) or Site-Specific Water Quality Objectives (SSWQOs), or Site Performance Objectives (SPOs). Additional clarity is warranted. Secondly, the Biotic Ligand Model is available to evaluate toxicological data. However and is often the case with existing toxicological data sets, they lack a complete list of model inputs (e.g., Dissolved Organic Matter). This is a data limitation and not a model limitation as implied by the text. It is acknowledged that to date, the BLM is only incorporated and considered in freshwater quality criteria for copper (USEPA 2007); but it should not be eliminated as a useful tool in evaluating site-specific data. Therefore, it is recommended that the text be modified to clearly identify why the BLM was not employed to evaluate the toxicological data; and that the draft guideline acknowledge the potential usefulness of the BLM when evaluating site-specific data. Reference: U.S. Environmental Protection Agency (USEPA). 2007. Aquatic Life Ambient Freshwater Quality Criteria - Copper, 2007 Revision. Office of Water. Office of Science and Technology, Washington, DC. EPA-822-R-07-001. February 2007.	The paragraph has been revised to state that the intent would be to adapt a WQG for site-specific conditions. In addition, the data limitations have been highlighted.
Teck Resources	Teck Resources	19	64	7-16	It is unclear as to the rationale applied in assigning an uncertainty factor associated with the determination of the proposed short-term maximum water quality guideline. Based on the text it would appear that LC50 and LC10 results from Mebane (2012) were used to select an uncertainty factor. Based on the data presented within lines 7 through 12, the LC50/LC10 ratio for the six tests are: 1.26, 1.50, 1.41, 1.63, 1.43, and 3.09. In consideration of the aforementioned LC50/LC10 ratios it is unclear how an uncertainty factor of 3.5 was determined. It is recognized and acknowledged that it is MOE policy to apply "uncertainty factors", but applying a policy decision under the veil of science is misleading. Based on the aforementioned ratios and as acknowledged within the draft guideline (see Line 14) where the ranges of ratios ranged from 1.26 to 3.09, it is not clear how a value of 3.5 was selected and appears arbitrary. Should an uncertainty factor be required due to policy why not use the average of the aforementioned data (e.g., 1.72)? As indicated by the data (see Figure 7), an uncertainty factor is not required.	BC's policy is to apply an uncertainty factor of 2-10 for guideline development to account for various sources of uncertainty. A re-evaluation of the critical studies used to derive the short-term WQG was conducted. Based on the re-evaluation, it was determined that the minimum uncertainty factor of 2.0 is appropriate for the short-term WQG.
Teck Resources	Teck Resources	20	65	1-3	Based on available toxicological data there are limitations in the database. In the case for the proposed short-term WQG, the range of water hardness values measured/tested to date is from 3.4 to 455 mg/L as CaCO3. We disagree with the language that implies that a "site-specific WQG should be bounded to this range." As previously noted, the use of "site-specific" in relation to a provincial WQG is unclear and should be clarified. Also, the range of water hardness and cadmium toxicity evaluated to date should not be implied as if the relationship is no longer applicable above a water hardness of 455 mg/L as CaCO3. Rather it merely reflects the range of data tested to date and that should site-specific water hardness values be greater than 455 mg/L as CaCO3 there is some uncertainty associated with the potential for adverse affects. Therefore it is recommended that the text be modified to reflect this uncertainty while still allowing practitioners the opportunity of confirming the presence or absence of cadmium toxicity in waters with hardness values >455 mg/L as CaCO3.	Guidance on the determination of the guideline for waters with hardness outside this range has been added to sections 9.4.1 and 9.4.2.

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Teck Resources	Teck Resources	21	66	11-14	Presently one data point from a secondary study is driving the proposed long-term average water quality guideline. As noted on lines 11-14, "Data from a study that did not report all of the information required to receive a primary or secondary classification indicated that no adverse effects on the feeding rates or brood mass of D. magna were observed at 0.051 µg/L Cd at 50 mg/L CaCO3 (Barata and Baird 2000)." This sentence is misleading as the aforementioned concentration of 0.051 µg/L Cd is only one data point and is not reflective of the complete data set from the referenced study. This study (Barata and Baird, 2000) is not of sufficient quality to be considered a primary study based on the quality ranking consistent with both BCMOE and CCME guidelines. Other available data for quantifying the same endpoint to the same organism were ignored. The lowest cadmium endpoint reported in this study is an EC10 of 0.13 µg/L based on reproductive effects. The EC10 was calculated using a linear regression of effects data and nominal cadmium exposure. A statistical test was also performed to determine that the lowest test concentration with effects was indistinguishable from the control (i.e., the NOEC or no-effect concentration). The NOEC for this same endpoint is reported as 0.2 µg/L, indicating that cadmium concentrations below and up to 0.2 µg/L produce results that are indistinguishable from controls. It was concluded that no adverse effects (relative to the control) were observed at a concentration of 0.2 µg/L, which is 54% higher than the EC10 calculated by Barata and Baird. An additional problem with using the lowest reported value is that this methodology does not consider whether the study producing the lowest number is replicable. Problems that may have impacted the quality of the study or the study results may be discovered by comparison with other published values for the same organism and endpoint. However, if the lowest value is always used, regardless of whether it agrees with other reported values, then outlier values could possibly determine the water quality guideline. Consideration of multiple sources of information for sensitive endpoints, when they are available, is preferable because the inappropriate influence of outlier values is diminished. Additional rationale should be provided justifying why one data point is being used to drive the proposed guideline. Furthermore, the application of an uncertainty factor simply being assigned as a mater of policy as opposed to incomplete science to the one data point requires further rationale. Whether the guideline is set to protect this one value directly or indirectly through the use of uncertainty factors, the end result is that a single value from a single study forms the basis for the draft guideline.	BC's protocol for developing water quality guidelines was used (http://www.env.gov.bc.ca/wat/wq/pdf/wq-derivation.pdf). The EC10 reported in Barata and Baird is not used in the derivation of the WQG.
Teck Resources	Teck Resources	22	67	1-3	Based on available toxicological data there are limitations with the database. In the case for the proposed long-term WQG, the range of water hardness values measured/tested to date is from 17 to 285 mg/L as CaCO3. We disagree that site-specific application of the proposed WQG should be bounded to this range. The range of water hardness and cadmium toxicity evaluated to date should not be implied as if the relationship is no longer applicable above a water hardness of 285 mg/L as CaCO3. Rather it merely reflects the range of data tested and that should site-specific water hardness values be greater than 285 mg/L as CaCO3 there is uncertainty that may warrant additional work. Therefore it is recommended that the text be modified to reflect this uncertainty while still allowing practitioners the opportunity of confirming the presence or absence of cadmium toxicity in waters with hardness values >285 mg/L as CaCO3.	Guidance on the determination of the guideline for waters with hardness outside this range has been added to sections 9.4.1 and 9.4.2. Included is a statement that recommends the development of site-specific water quality objectives in these situations.
Teck Resources	Teck Resources	23	68	29-35	Language associated with use of uncertainty factors appears contrary to the primary purpose associated with the application of uncertainty factors as determined by MOE. As noted within the Introduction of the draft guideline, application of uncertainty factors are to account for uncertainties that may include factors such as other stressors including cumulative effects, multiple contaminants, indirect effects etc. The text in this section implies that uncertainty factors are in consideration of when cadmium is the only contaminant of concern. As a result, there appears to be an inconsistency in the application of a uncertainty factor within the draft document.	The text has been revised to add clarity.
Teck Resources	Teck Resources	24	69	Section 9.4.4	Existing language should be refined to acknowledge the level of conservatism being incorporated into the proposed draft guideline. As presently written, it implies that an exceedance of the guideline represents a level of unacceptable risk. It is critical to effectively communicate that an exceedance of the draft WQG does not, nor should it be interpreted, as representing an unacceptable risk or that adverse effects are occurring; rather, exceedance is an indication that additional investigation(s) may be warranted. In short, the proposed guideline is a screening level tool.	Text in the Introduction has been revised as per Teck comment #1.
Teck Resources	Teck Resources	25	71	28-34	We are pleased to see the recognition of the Biotic Ligand Model (BLM) as a useful tool to more accurately evaluate the potential for effects of ambient water quality, but would like to point out the BLM is not restricted to the application of fish, but rather is appropriate at a biotic ligand site. As a result, it is also applicable to invertebrates.	This section has been revised to include aquatic invertebrates.