

Table 1. Substantive comments on the draft sulphate water quality guideline posted for external review on October 2012.

Source	Affiliation	Page#/Line#	Comment #	Comment	Response
Kory Ryde	Agriculture and Agri-Food Canada		1	I reviewed the guideline and the supporting documents and could not add anything significant.	Thank you.
Craig Buday	Environment Canada		2	You have written a very detailed & comprehensive guideline report.	Thank you.
Jo-Ann Aldridge	Environment Canada		3	Although background surface water concentrations were considered in development of the standard, it appears that background groundwater concentrations may not have been adequately considered. Baseflow from groundwater can dominate water quality in many freshwater streams. As such, the guidelines may be more defensible if the ranges of background groundwater sulphate concentrations are considered. EC looked at the wells in the Abbotsford–Sumas Aquifer near to Fishtrap Creek where sulphate levels are routinely measured in the range from of 55 - 160 mg/L as part of EC's monthly monitoring program. Corresponding water hardness is in the range of 112 - 229 mg/L. The proposed hardness-dependent water quality guidelines for this water would be 270 mg/L or higher (410 mg/L). So, considering the example of groundwater contribution to freshwater baseflow in the Abbotsford-Sumas aquifer, the background sulphate concentrations should meet proposed guidelines.	The sulphate water quality guideline is a surface water guideline.
James Elphick	Nautilus Environmental for Mining Association of British Columbia		4	The guideline document is well-written and appears to be an appropriate assessment of the available information on the toxicity of sulphate to aquatic organisms. BCMoE has addressed a number of concerns that were raised with respect to the first draft guideline, including obtaining additional data for trout, which now form the basis of the guideline. In general, the approach that has been used appears to be sound.	Thank you.
James Elphick	Nautilus Environmental for Mining Association of British Columbia	15/7	5	suggest adding "Omineca Peace" to the list of notable locations.	We have added "Omineca-Peace".
James Elphick	Nautilus Environmental for Mining Association of British Columbia	17/9-11	6	suggest deleting this sentence, since its context and relevance with respect to the previous information in the paragraph is unclear.	The sentence has been removed.
James Elphick	Nautilus	17/13	7	suggest adding "chronic" before the word "toxicity".	We have added "chronic".

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	Environmental for Mining Association of British Columbia				
James Elphick	Nautilus Environmental for Mining Association of British Columbia	19/6	8	this is an unusual speculation about sulphate being large and bulky. In our laboratory, we have seen active and effective regulation of internal sulphate across a range of external sulphate concentrations in common test organisms, such as <i>Daphnia magna</i> and <i>Pseudokirchneriella subcapitata</i> .	This was taken directly from Conley et al. (2010) presentation at SETAC. Their talk was titled "Preliminary investigations of TDS toxicity and sulfate trafficking in mayflies".
James Elphick	Nautilus Environmental for Mining Association of British Columbia	19/13	9	suggest adding "resulting in" at the end of this line.	We added "with" to the sentence.
James Elphick	Nautilus Environmental for Mining Association of British Columbia	20/17	10	after "toxicity" suggest adding "and toxicity-modifying effect".	We added "and toxicity-modifying effect".
James Elphick	Nautilus Environmental for Mining Association of British Columbia	21/1-3	11	It is important to note that the toxicity of magnesium reported by these authors occurred in water with very low ionic strength, and under ratios of Mg:Ca of 10:1 that would be considered highly unusual in British Columbia. The current wording, "Mg <sup>2+</sup> can be toxic at very low concentrations to species that inhabit low ionic strength surface waters" is true; however, it implies a much greater risk than is actually the case. As with all of the major ions, the ratios between the ions (e.g., Na:K; SO <sub>4</sub> :Cl; SO <sub>4</sub> :Ca; Cl:Ca; Mg:Ca) are very important in altering effects levels, and data for tests where one of these ratios is highly unusual (in this case, Mg>>Ca) is not of much relevance to understanding the risk of adverse effects. In line 1 of page 21, after "reported in the literature", suggest adding "in unusual cases where Ca is substantially lower than Mg."	We added "in unusual cases where Ca is substantially lower than Mg" as suggested.
James Elphick	Nautilus Environmental for Mining Association of British Columbia	21/28	12	Typo – "has" should be "have".	Corrected.
James Elphick	Nautilus Environmental for Mining Association of British Columbia	29/1-2	13	the LOEC values for reproduction of <i>Ceriodaphnia dubia</i> were not higher than the LC50 values for this species, as is stated here.	We clarified this sentence. The LOEC values for moderately hard (80 mg/L) and hard (160 mg/L) water were higher than their IC50 values.
James Elphick	Nautilus Environmental for Mining Association of British Columbia	29/10	14	it should be made clear in this section that it is not water hardness increasing above 160 mg/L that presents an osmotic challenge, but rather that total ionic strength of waters with elevated hardness,	We have added "and associated increased total ionic strength of waters".

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				<p>sulphate, and other major ions may combine to cause osmotic stress. <i>C. dubia</i> can quite happily reproduce at hardness of as high as 500 mg/L, for example, as long as the total ionic strength does not get too high.</p>	
James Elphick	Nautilus Environmental for Mining Association of British Columbia	30/4	15	<p>the wording “Experiments from all 3 groups of studies had difficulty achieving a control (zero concentration) for sulphate” should be changed, since it implies that attempts were made to achieve a “zero concentration”, but that the studies somehow failed in that regard. This could be changed, as follows: “Experiments from all three groups of studies had control concentrations that were not 0 mg/L sulphate, since sulphate is a major ion present in all natural waters.”</p>	<p>We have changed the sentence to read “Experiments from all 3 groups of studies had control concentrations that were not 0 mg/L sulphate”.</p>
James Elphick	Nautilus Environmental for Mining Association of British Columbia	30/10-11	16	<p>it is not clear what this means.</p>	<p>This sentence has been removed.</p>
James Elphick	Nautilus Environmental for Mining Association of British Columbia	35/11-12	17	<p>models where the LC10, LC25 or LC50 were equal are not relevant toxicological models, and should be deleted from this document, since there is no toxicological basis upon which one might anticipate the LC25 to be the same among water types, but the LC10 and LC50 different. This approach implies that different organisms respond differently to the effect of the variable (in this case, hardness), with some organisms becoming more sensitive to the chemical, and others less sensitive, as a result of the modifying factor.</p>	<p>References to the Common LCxx models have been removed from the document.</p>
James Elphick	Nautilus Environmental for Mining Association of British Columbia	35/16	18	<p>see comments above; the Common LCxx models should be deleted, unless rationale can be provided to explain why this phenomenon might occur.</p>	<p>See response to comment 17</p>
James Elphick	Nautilus Environmental for Mining Association of British Columbia	35/27	19	<p>this example should be changed, since the Common LC10 model should not be used.</p>	<p>See response to comment 17</p>
James Elphick	Nautilus Environmental for Mining Association of British Columbia	39/Table4	20	<p>suggest deleting the data for rainbow trout produced by the PESC lab, since the tests have been repeated, and much more reliable data are available from the Kennedy tests. In addition, the LC values for <i>E. complanata</i> should be re-estimated after removing the Common LC10 model, and inclusion of a natural response.</p>	<p>We disagree with removing the rainbow trout data produced by the PESC lab. Guidelines were developed using the data from the Kennedy tests. The Common LCxx models have been removed and the data has been re-analyzed.</p>
James Elphick	Nautilus	40/Table6	21	<p>We disagree that the data from Elphick <i>et al.</i> (2011)</p>	<p>At a minimum, substance concentrations must be measured at</p>

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	Environmental for Mining Association of British Columbia			should be considered secondary. In the case of <i>Brachionus</i> and <i>Pseudokirchneriella</i> , sulphate could not be measured at the end of exposure, due to the small test volumes. For all other species, sulphate was measured in all concentrations at the start, and in the concentrations that bracketed the effect level(s) at the end of exposure. From a data quality standpoint, this degree of effort ensures that there is sufficient information to characterize start and end concentrations within the range of interest.	the beginning and end of the exposure period for data to be classified as primary as stated in both the BC and CCME water quality guideline development protocols.
James Elphick	Nautilus Environmental for Mining Association of British Columbia	41/8-13	22	the rainbow trout data from the PESC lab are of poor quality and have been replaced with a much more robust dataset from the Kennedy lab. It would be best to delete the PESC data from the guideline entirely, since including them implies that there is value in the data provided from that study.	We disagree with removing the rainbow trout data produced by the PESC lab. Although the Kennedy data is more robust, the PESC data did pass the 35% threshold (Taylor personal communication). More importantly the modification to the protocol which used eyed eggs removes the more sensitive pre-eyed egg life stage as stated by Dr. Taylor. We have clearly noted this in the guideline as suggested by Dr. Taylor.
James Elphick	Nautilus Environmental for Mining Association of British Columbia	42/4	23	the LC10 for <i>E. complanata</i> should not be reported on the basis of the Common LCxx model that was used.	See response to comment 20.
James Elphick	Nautilus Environmental for Mining Association of British Columbia	42/7	24	suggest adding the words "the embryo stage of" prior to "chinook".	We have added "the embryo stage of" prior to chinook as suggested.
James Elphick	Nautilus Environmental for Mining Association of British Columbia	43/6	25	replication was actually not increased, since if you assume each container is a replicate, this would be considered pseudo-replication. Suggest changing the word "replication" to "sample size".	We changed "replication" to "sample size" as suggested.
James Elphick	Nautilus Environmental for Mining Association of British Columbia	43/17	26	suggest adding the word "progressively" before "protective".	We added the word "progressively" as suggested.
James Elphick	Nautilus Environmental for Mining Association of British Columbia	43/17	27	the freshwater mussel should be removed here based on the re-analysis of data without the Common LCxx model.	The Common LCxx model was removed and the data was reanalyzed.
James Elphick	Nautilus Environmental for Mining Association of British Columbia	43/29	28	suggest adding "indicating a low degree of confidence in the estimate" to the end of this sentence.	We have added the suggested wording.
James Elphick	Nautilus Environmental for Mining Association of British Columbia	45/Figure8	29	This figure should be updated following re-analysis of the <i>E. complanata</i> dataset. Three of the LC10 values that fall below the guideline are for this species, and this indicates a potential risk to this species, when in fact there is not one.	We have re-analysed the data and revised the figure.

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B. Zajdlik	Zajdlik & Associates Inc. on behalf of Mining Association of BC	Pg. 46, Table 7, technical appendix	30	<p>Using the modelling procedure used by BC MOE, additional models were explored. The model best supported by the information theoretic criterion AICc used by BC MOE was identical in structure to the model most strongly supported by analyses conducted by BC MOE. However the link function (probit) used by BC MOE was not nearly so strongly supported by the data as the logit link.</p> <p>The LC20s estimated using the latter model differ somewhat from those used to generate results in Table 7, pg. 46. These latter estimates, being better supported by the data should be used to estimate sulphate guidelines.</p>	We have re-analyzed the data and included the logit link. We have updated our Tables and Figures to reflect the changes.
B. Zajdlik	Zajdlik & Associates Inc. on behalf of Mining Association of BC	Pg. 46, Table 7, technical appendix	31	<p>Once LC20s are estimated, most jurisdictions use the LC20s in a species sensitivity distribution (SSD) to estimate a low percentile of the combined toxicity test endpoints that becomes the environmental quality guideline. British Columbia is to the best of my knowledge the only jurisdiction that has not adopted this approach to estimating water quality guidelines. Instead British Columbia uses a less desirable safety factor approach. BC MOE should consider using the SSD to estimating water quality guidelines.</p>	<p>BC has a protocol for developing water quality guidelines and the protocol can be found at <a href="http://www.env.gov.bc.ca/wat/wq/wq_procedure.html">http://www.env.gov.bc.ca/wat/wq/wq_procedure.html</a>. The CCME data preference is for ECx values representing a no-effect level to be included in their SSDs, preference is not given to LC20 values. BC does not endorse the CCME SSD approach.</p>
B. Zajdlik	Zajdlik & Associates Inc. on behalf of Mining Association of BC	Appendices D and E	32	<p>The analyses presented in appendices D and E represent nominal sulphate measurements whereas the draft sulphate guidelines are based on measured sulphate concentrations using analyses that are not presented. As the guidelines derived using the results in appendices D and E differ from those presented as sulphate guidelines, the analyses supporting the draft sulphate guidelines should be presented.</p>	<p>The data that was presented in the draft sulphate guidelines was from measured concentrations. We had re-run the data using the measured concentrations. We have re-analyzed the data and included the logit link as you suggested. The updated appendices show the results using the measured data.</p>
Martin Davies	Hatfield Consultants	7	33	<p>For waters with hardness of 250 mg/L or greater and sulphate concentrations that fall below the proposed sulphate guideline of 410 mg/L for waters with hardness less than 250 mg/L (for example, water with hardness of 260 mg/L and a sulphate concentration of 350 mg/L), what sulphate guideline would apply? Would the 410 mg/L guideline for lower-hardness waters apply, or would development of a site-specific SO4 objective be required, despite the SO4 concentration meeting a lower-hardness-</p>	<p>Water quality guidelines are intended for generic provincial application and do not account for site-specific factors. Site specific conditions would require consultation with regional Environmental Protection Division staff to ensure water uses are protected.</p>

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				level guideline?	
Martin Davies	Hatfield Consultants	45	34	Regarding potential effects of sulphate on mayflies, a large amount of invertebrate-community data exists for many creeks throughout BC (and certainly elsewhere) with relatively high concentrations of sulphate. These datasets could quickly be assessed to examine the potential for effects on mayflies and other invertebrates. More broadly, this document relies entirely on laboratory data, when there are likely dozens of streams (often mine-influenced) with high sulphate levels and substantial amounts of fisheries and/or invertebrate community data that could be used as a "reality check" for the laboratory work and this and other proposed guidelines.	See comment 33.
Trevor Davies			35	First, I'd like to commend the ministry for taking a second look at the previously published sulphate guideline. Coming up with a reasonable and responsible guideline for something as ubiquitous as a salt is no easy task. As I'm sure you know, my master's research was based on re-examining the guideline and can fully relate how sometimes confusing salt toxicity can be. Congratulation on getting the guideline redone.	Thank you.
Trevor Davies			36	I have three major points, two of which are editorial in nature. Of greatest concern is the absence of a maximum discharge limit that I feel is unacceptable and needs to be reconsidered. Although I think the allowable sulphate discharge concentrations at various levels of water hardness are reasonable, I am concerned about the absence of a maximum short term discharge concentration. Indeed, I see no scientific basis to use only a monthly average, as I am unaware of any research that has been done on the chronic and/or acute effects of the effects of relatively low level mean exposures that are interspersed with short term high level sulphate concentrations. Simply, there is no scientific basis to allow a monthly average concentration when the only research has been done has been on constant sulphate concentrations. Under the scenario currently proposed, it would be possible to have sulphate discharges well in excess of acute thresholds and still be under the proposed monthly allowable discharge limit. Without some upper limit explicitly detailed in the guideline I fail to see how this guideline provides adequate protection for	Page 22 of our protocol states: "The averaging period approach is a refinement to the existing guideline approach, reflecting more closely the thresholds of average toxicity. This approach allows concentrations of a substance to fluctuate above and below the guideline provided that the average is met over the specified averaging period. The goal is to provide a balance between acceptable levels of protection to counter chronic toxicity without being too stringent, and the practical application of the guidelines in terms of monitoring requirements. The averaging period for the chronic guideline may differ depending upon the substance under investigation and is somewhat arbitrary (e.g. 5 in 30 days have been used for BC water quality objectives and guidelines). These averaging periods were chosen as reasonable and practical durations to address chronic effects and to fit into monitoring timetables for provincial agencies. Five samples are considered the minimum needed to calculate the average; however, in some cases where the concentrations fluctuate widely in nature, more than 5 samples may be necessary. On the other hand, if concentrations are uniform and rarely exceed the chronic guideline, less frequent monitoring may be justified. In this case, failure of any individual sample to meet the chronic

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				aquatic life.	<p>guideline would serve as an alert signal to increase the monitoring."</p> <p>We were unable to develop a short-term maximum guideline at this time due to data limitations.</p>
Trevor Davies			37	<p>To quote from the text: "Also, striped bass is an Atlantic species, whereas toxicity tests using native species are more desirable for developing water quality guidelines in BC."</p> <p>I am somewhat embarrassed as I think this quote may be a quite originally attributed to me. Unfortunately, the reasoning behind this point is simply incorrect. If the BC guideline was based on a census of the aquatic species found in BC then this would be an acceptable justification for rejecting the striped bass data point, however, the guideline instead is based on a sample of a relatively few number of species that we all hope are representative of the sulphate sensitivity the aquatic organisms found in BC. Because we are only taking a sample, any organism that shows sulphate sensitivity potentially provides us with information about the potential acute and/or chronic effects that sulphate may have on other aquatic species and therefore no species should be discarded out of hand simply because it is not native to BC. Having said all that, the striped bass data point should not be used simply because striped bass larvae are extremely difficult to culture, transport, and conduct toxicity tests on. I never did publish my research on striped bass simply because I was never confident that the toxicity I was observing was due to sulphate toxicity rather than other factors. This is a long winded way of saying this reasoning should be removed and/or reworded. Point of interest: striped bass were introduced to San Francisco Bay in 1879 and are now found on the west coast.</p>	<p>Thank you for your clarification. The statement is actually correct; toxicity testing on native species is more desirable for developing guidelines in BC. While all toxicity data is considered in the guideline development process, we have minimum data requirements for species that are resident in BC.</p> <p>The concerns you raised regarding the validity of the striped bass study were valid.</p>
Trevor Davies			38	<p>The wording about the statistical tests that were employed really needs to be changed. Specifically the assertion in both the main text and in appendix B that "Maximum likelihood estimates are asymptotically the best possible estimates and extract the maximum amount of information from the data" is simply not true. First, MLE is an excellent and standard technique for parameter</p>	<p>Maximum likelihood estimates are asymptotically fully efficient. This means that no asymptotically unbiased estimator has lower asymptotic mean squared error than the MLE (or other estimators attaining this bound). So no other method can give a smaller SE as the sample size increases, i.e. it extracts all the information from the data. See, for example, <a href="http://fds.oup.com/www.oup.com/pdf/13/9780198572268.pdf">http://fds.oup.com/www.oup.com/pdf/13/9780198572268.pdf</a></p>

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				estimation and as far as I can tell the statistics that were employed appear both reasonable and correct. However, the assertion that MLE somehow extracts the 'maximum amount of information from the data' is incorrect and also quite a puzzling thing to see in print. Simply because one employs a MLE approach to parameter estimation does not mean that correct parameters or the 'maximum amount of information will be extracted from the data (whatever that means)' has been achieved. Indeed, MLE can suffer from obtaining parameter estimates that are biologically impossible yet mathematically possible under the model formulation that the MLE is being applied. Further, depending on the model and contrast of the data, the likelihood surface can have multiple minima that can potentially result in erroneous estimates to be identified. Of course, a careful statistician and careful model formation and testing can help to avoid these problems, however, the assertion that somehow MLE can extract the 'maximum amount of information' as it stands is simply not incorrect. This wording really needs to be changed.	A true MLE will respect any biological constraints that are applied. It may turn out that an analyst may ignore the biological constraints, but this is not the fault of the MLE.  We have removed this sentence from the technical appendix.
Monica Nowierski	Ontario Ministry of the Environment	6/4	39	Identify the value of the maximum water quality guideline (2000)	We added the 100 mg/L to the document.
Monica Nowierski	Ontario Ministry of the Environment	7/4	40	Consider replacing the USGS water hardness categories with the CCME water hardness categories. Very soft (0-30 mg/L), soft (31-60 mg/L), moderately soft/hard (61-120 mg/L), hard (121-180 mg/L) and very hard (>180 mg/L).	We replaced the water hardness categories with adapted CCME categories.
Monica Nowierski	Ontario Ministry of the Environment	9/25	41	replace "determining" with "determine"	Corrected.
Monica Nowierski	Ontario Ministry of the Environment	10/2	42	re uncertainty factor; provide reference to your criteria derivation protocol here which would describe the uncertainty factors that can be used and when.	We added the reference.
Monica Nowierski	Ontario Ministry of the Environment	15/21	43	Table 1 - suggest reporting levels separately for lakes, and rivers/streams, as concentrations may be significantly higher in rivers/streams when compared to lakes.	Good suggestion however this would take a lot of work and will not change the guideline values. We will consider doing this in future guidelines.
Monica Nowierski	Ontario Ministry of the Environment	17/3	44	The document states that "Until recently, the majority of studies have focussed on the acute toxicity of sulphate to aquatic invertebrates.". Why could a maximum exposure value not be derived?	There was not enough data to fulfill the minimum data requirements for resident species in BC.
Monica	Ontario Ministry of	19/13	45	add "with" to end of sentence ("with" 96-h LC50s	We added "with".

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Nowierski	the Environment			of...)	
Monica Nowierski	Ontario Ministry of the Environment	25/10	46	High <i>Hyalella</i> control survival is possible in low hardness / low alkalinity water. See Borgmann et al 2005. Effect of major ions on the toxicity of copper to <i>Hyalella azteca</i> and implications for the biotic ligand model. <i>Aquatic Toxicology</i> 73 (2005) 268–287	<p>In the 1996 testing at PESC, the 25 mg/L water hardness followed the 1985 USEPA recipe, which had a low concentration of chloride. This combination of low hardness &amp; low chloride could be stressful to the survival of the control <i>Hyalella</i>. In the 2007 testing, the 25 mg/L water hardness followed the 1994 USEPA recipe, which had a higher concentration of chloride. This combination of low hardness &amp; higher chloride was less stressful to the survival of the control <i>Hyalella</i>.</p> <p>We will change the wording to read “It may be that the combination of 25 mg/L water hardness (as CaCO<sub>3</sub>) with a low concentration of chloride could be stressful for the survival of <i>H. azteca</i> (Buday personal communication 2010).”</p>
Monica Nowierski	Ontario Ministry of the Environment	25/25	47	England/Wales have an environmental quality standard for sulphate for aquatic life protection of 400 mg/L (annual average). {Notes: Total anions of 250 mg/l as an annual average also proposed. Allowable annual average concentrations of chloride, sulphate and nitrate present jointly should be derived from: $X + Y/1.5 + Z/1.8 < C$ , where: X = concentration of Cl <sup>-</sup> , Y = concentration of SO <sub>4</sub> <sup>2-</sup> , Z = concentration of NO <sub>3</sub> <sup>2-</sup> and C = relevant standard for chloride (ie 250 mg l <sup>-1</sup> ). Total anions concentration 'normalised' to Cl <sup>-</sup> by Cl <sup>-</sup> = SO <sub>4</sub> <sup>-</sup> /1.5 = NO <sub>3</sub> <sup>2-</sup> /1.8.} [criteria derivation document attached]	Thank you.
Monica Nowierski	Ontario Ministry of the Environment	25/25	48	Please indicate the sulphate criteria values available from other jurisdictions, for comparison purposes.	The draft guideline does mention that Illinois and Iowa implemented water quality standards for sulphate based on levels of chloride and water hardness. Minnesota has established a sulphate standard of 10 mg/L to protect wild rice. The reader can refer to the references for more information. Note: BC has policies and protocols that it follows when developing guidelines. These may differ from other jurisdictions.
Monica Nowierski	Ontario Ministry of the Environment	28/15	49	Indicate that the Elphick et al 2011 data is summarized in Appendix C.	We added that the data is summarized in Appendix C.
Monica Nowierski	Ontario Ministry of the Environment	28/28	50	The following is stated: "The lowest endpoint guidelines proposed by Elphick et al. (2011) using LOEC values from <i>C. dubia</i> and a minimum uncertainty factor of 2 were: 75, 625, and 675 mg/L sulphate for soft (10 – 40 mg/L), moderately hard (80 – 100 mg/L) and hard water (160 – 250 mg/L), respectively. However, the LOEC values used for	They did not propose criteria for other levels.

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				their proposed guidelines were higher than the LC50 values for the same species which is problematic and would not be considered protective." What criteria did Elphick propose for the hardness levels not included in the listed ranges?	
Monica Nowierski	Ontario Ministry of the Environment	29/4	51	The document states that "Elphick et al. (2011) were unable to develop a clear sulphate toxicity/water hardness relationship that applied across species and endpoints." Is a hardness-based guideline justifiable, based on results of one long-term study (RBT early life stage study conducted by SFU)?	This is an unusual situation. Normally, we would want to see a clear sulphate toxicity/water hardness relationship that applies across species. In this situation the most sensitive species was RBT early life stage which demonstrated some amelioration from increased water hardness. We made sure that other species tested were also protected at the proposed levels for the different water hardness categories.
Monica Nowierski	Ontario Ministry of the Environment	29/7	52	The following is stated: "While the IC25 values for <i>C. daphnia</i> and <i>B. calyciflorus</i> reproduction showed decreased sulphate toxicity with increasing water hardness up to a water hardness of 160 mg/L, sulphate toxicity increased when water hardness increased from 160 to 320 mg/L. The authors suggest that increasing water hardness above 160 mg/L CaCO <sub>3</sub> could present osmotic challenge for some species (e.g. <i>C. dubia</i> ). Mining activities in BC commonly result in increased sulphate and hardness in surface waters, and in many cases, water hardness is well above 160 mg/L." If this is the case, then perhaps BC should consider capping the proposed guideline at a hardness of 160 mg/L (e.g. not allowing for increased sulphate above 160 mg/L as CaCO <sub>3</sub> , where BC now states that a sulphate concentration of 410 mg/L is allowed in very hard water (181-250 mg/L) and not to exceed sulphate levels should be determined based on site water chemistry when hardness >250 mg/L as CaCO <sub>3</sub> .	The guideline is based on the natural background water hardness and we did not extrapolate outside the dataset. The <i>C. dubia</i> endpoint for reproduction in very hard water had a very large confidence interval indicating a low degree of confidence in the estimate. Future studies with increased sample size may improve the estimate. The <i>C. dubia</i> study was classified as secondary whereas the RBT early life stage study was classified as primary.
Monica Nowierski	Ontario Ministry of the Environment	30/5	53	In the hardness-toxicity tests, studies that utilized measured concentrations of sulphates should only be used since, as stated in the criteria document, "Increasing water hardness (via increasing Ca <sup>2+</sup> and Mg <sup>2+</sup> ) increased sulphate concentrations in treatments since the source for Ca <sup>2+</sup> and Mg <sup>2+</sup> was CaSO <sub>4</sub> and MgSO <sub>4</sub> . The experiments from each group of studies incorporated a control that was comprised of the base water with no additional sulphate beyond that already present in the water type."	We agree. We classified the studies as primary or secondary based on whether concentrations were measured at the beginning and end of the exposure. The estimates used to develop the guidelines are from measured concentrations.
Monica Nowierski	Ontario Ministry of the Environment	31	54	Table 3 - would be nice to have the same description regarding number of sulphate concentrations and number of hardness levels used for each test	Agreed. We added more detail.

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				throughout the entire table, as was completed for the description of the Kennedy study.	
Monica Nowierski	Ontario Ministry of the Environment	32/1., Appendix D	55	I don't feel I have the statistical expertise to comment on whether or not CETIS (Environment Canada endorsed software) provides the appropriate models and fitting to derive benchmark doses.	No response needed.
Monica Nowierski	Ontario Ministry of the Environment	32/3	56	replace "on the data provided PESC, ..." to "on the data provided by PESC, ...."	Corrected.
Monica Nowierski	Ontario Ministry of the Environment	32/4	57	Regarding "Only organisms exposed to at least 2 levels of water hardness were used for the statistical analysis.". Selection of studies to use in the assessment of hardness toxicity relationships for hardness-adjusted CWQGs follows guidance of EPA. Definitive acute values had to be available over a range of hardness such that the highest hardness is at least three times the lowest, and such that the highest is at least 100 mg/L higher than the lowest (U.S. EPA. 2001.2001 Update of ambient water quality criteria for cadmium. Washington, D.C., Office of Water.).	The guidance provided from US EPA was provided for updating the cadmium water quality criteria. A clear protocol or guidance document on the selection of studies, number of species required etc. in the assessment of toxicity modifying factors such as water hardness is needed. Neither CCME or BC currently have guidance on this.
Monica Nowierski	Ontario Ministry of the Environment	'37/25, Appendix E	58	In consultation with an in-house (Ontario MOE) statistician, the following is a comment related to model averaging. "If we begin to use an average model, there are concerns that we will move from using the most-sensitive species' response to the average species response – this change could have significant impacts on our ability to protect the environment".	Model averaging does not occur over species, but only over models within each species. So the LCxx are not averaged across species.
Monica Nowierski	Ontario Ministry of the Environment	41/21	59	The following is stated: "The Pacific tree frog became more sensitive to sulphate by increasing water hardness from 15 to 80 mg/L (28-day LC10 of 648 (345-1,218) mg/L to 28-day LC10 of 186 (65-531) mg/L, respectively). Other species (e.g. <i>Ceriodaphnia</i> and <i>Brachionus</i> ) showed decreases and increases in toxicity with increasing water hardness depending on the levels compared." Is a hardness-adjusted guideline justifiable, based on one ELS RBT study?	We agree that not all species showed decreased toxicity with increasing water hardness. The sulphate guideline is a special case. The ELS RBT was identified as the most sensitive species and did demonstrate some modified toxicity with increasing water hardness to 250 mg/L. The water quality guidelines proposed for the different water hardness categories are still protective of all other species tested. 3 species (EC10 values) fell below the guideline, 2 of these species were classified as secondary ( <i>C. dubia</i> and Pacific treefrog) and all had very large confidence intervals indicating a low degree of confidence in their estimates.
Monica Nowierski	Ontario Ministry of the Environment	44/2	60	Hardness is a continuous variable like any other water chemistry parameter and it should be used that way – as a continuous variable rather than a series of classes. Deriving a different sulphate water quality criteria for a hardness of 58 versus 62 mg/L as CaCO3 does not seem to be easily justifiable.	In order to use hardness as a continuous variable, you need to decide how the dose-response curve will vary as a function of hardness. There are several possibilities. (a) Both the location of the curve (e.g. the dose at the LC50) and the steepness of the dose-response curve vary with hardness. In this case, with exactly 2 hardness levels, then

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				Perhaps this is not the best approach for deriving hardness-based sulphate criteria for BC waters. Care should be taken when applying hardness-based criteria to surface waters (e.g. those that have naturally high hardness versus those that have anthropogenically elevated hardness due to industrial discharges, for example).	<p>treating hardness as a categorical variable or as a continuous variable will give the same results. With 3 or more hardness levels, you then have to decide if the relationship of the location and of the slope against hardness is linear. Using hardness as a categorical variable will give similar results.</p> <p>Next you could decide that the steepness of the dose-response curve is the same across all hardness levels, but only the location changes (i.e. the curve just shifts left or right). Again, with two levels of hardness, there is no difference vs treating hardness as a categorical variable, and with 3+ levels, there won't be much change.</p> <p>We agree that care should be taken when applying the hardness-based guideline to BC waters. The hardness adjusted guideline is based on natural background water hardness not anthropogenically elevated water hardness.</p>
Monica Nowierski	Ontario Ministry of the Environment	Appendix A, page 2	61	For derivation of water quality criteria, toxicity tests with <i>Hyalella</i> should be conducted using water only exposures with sterilized cotton gauze as a substrate, not sediment (e.g. Imhoff settling cones). See Borgmann et al. 1989. Toxicity Test Procedures for <i>Hyalella azteca</i> , and Chronic Toxicity of Cadmium and Pentachlorophenol to <i>H. azteca</i> , <i>Gammarus fasciatus</i> , and <i>Daphnia magna</i> . Arch. Environ. Contam. Toxicol. 18, 756-764; Borgmann et al. 1990. Relationship between Chronic Toxicity and Bioaccumulation of Cadmium in <i>Hyalella azteca</i> . Can. J. Fish. Aquat. Sci., 48:(1055-1060)	For testing the 28-day Borgmann test in Imhoff settling cones PESC has always preferred to use clean washed control sediment as the substrate. They have done this historically for all of their 28-day growth & survival tests with <i>Hyalella</i> . The use of control sediment as a substrate did not affect the sulphate concentrations.
Monica Nowierski	Ontario Ministry of the Environment	Appendix B, page 5	62	Is the 6 mg/L as CaCO <sub>3</sub> exposure water used in the RBT ELS hardness exposures dechlorinated municipal tap water (as was used for incubating eggs to reach eyed egg stage), or was recon water used? If tap water was used, how do the ratios of various ions differ from the recon water used for the other hardness exposures (50, 100, 250 mg/L as CaCO <sub>3</sub> )?	The water was de-chlorinated tap water and was not made up of any specific ratio. At this low level it likely does not matter (Kennedy personal communication).
Monica Nowierski	Ontario Ministry of the Environment	Appendix B, page 5	63	Was there any consideration given to conducting RBT egg (chorion) water-hardening in the water hardness-sulphate combination that is to be used for the duration of the 21 day exposure? Having the eggs water-harden, and reach eyed-egg stage in dechlorinated municipal tap water (6 mg/L hardness, with some sulphate present), and then transferring to the respective hardness-sulphate combination may obtain different results. This is important considering the RBT ELS exposure was the critical	The Kennedy study was designed to replicate what PESC did (with increased samples size) however, you raise a good point. Dr. Taylor (personal communication) raised some concerns with the modified EPS1/RM/28 method and stated that the pre-eyed eggs would be a more sensitive life stage. We have noted this in the updated guideline. Future studies should include water-hardening and the pre-eyed life stage to ensure the most sensitive life-stage is being assessed. This provides further justification for applying an uncertainty factor to determine the guideline.

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				study used in derivation of the guideline.	
Liam Mooney	Cameco Corporation	6/25	64	Why is a safety factor of two used in the derivation of the water quality guideline? Provide the scientific rationale for the use and selection of the safety factor.	BC applies uncertainty factors as part of the process for developing water quality guidelines as per our protocol (see Derivation of Water Quality Guidelines to Protect Aquatic Life in British Columbia posted on our website <a href="http://www.env.gov.bc.ca/wat/wq/wq_procedure.html">http://www.env.gov.bc.ca/wat/wq/wq_procedure.html</a> ). Two is the minimum uncertainty factor used in developing water quality guidelines.
Liam Mooney	Cameco Corporation	7/15-16	65	What are the human health and livestock guidelines based on? Provide references for the human health and livestock guidelines because they are adopted rather than independently derived.	See Section 8.1 for drinking water guidelines and 9 for livestock guidelines.
Liam Mooney	Cameco Corporation	23/19-21	66	Please be clear when presenting data that defines endpoints. Identify the endpoint used and the duration of the test that defined the toxic endpoint of 100 mg/L.	The duration of the test was one week and endpoint was mortality. Data was originally taken from Aquire database. NR-LETH MOR.
Liam Mooney	Cameco Corporation	23/23-27	67	The data from Singleton (2000) on the stimulation of bacteria from sulphate. Remove the fourth piece of evidence in Section 6.0 because it was not used to derive the current BC sulphate guideline. It was only used to stimulate future research, as mentioned in the text.	It was one of the pieces of evidence that was referenced when the guideline was originally developed by Singleton in 2000.
Liam Mooney	Cameco Corporation	27/27-29	68	The revised livestock value should be adopted only after it has been reviewed. Change the sentence to state that the livestock value will be adopted upon review and acceptance by the BCMOE.	We have changed the sentence as suggested.
Liam Mooney	Cameco Corporation	28/16-19	69	Elphick et al. (2011) did not specify that the guidelines derived were specific to BC. Revise the text to reflect the application of the values presented by Elphick et al. (2011).	We have removed "for BC".
Liam Mooney	Cameco Corporation	28/23-24	70	The CCME is not testing the SSD approach. The SSD approach is currently the recommended approach in Canada when a complete data set is available. The use of safety factors is recommended as a secondary approach if appropriate data does not exist. Correct the wording in this sentence to reflect that the CCME recommends the use of the SSD.	Although the CCME recommends the use of the SSD approach when there is sufficient data to do so, it is in the test phase. This method will be reviewed by the Water Quality Task Group in the future.
Liam Mooney	Cameco Corporation	28/26	71	Present a more objective view of the two methods of deriving water quality guidelines. The SSD approach is more objective than the lowest value approach used by the BCMOE. The lowest value approach relies heavily on the profession judgement through the selection and application of safety factors and the lowest endpoint. The SSD approach incorporates multiple endpoints and statistical analysis is used to derive the guideline – not a safety	See comment 31.

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				factor.	
Liam Mooney	Cameco Corporation	28/24-26	72	Through the endorsement of the SSD approach by the CCME, which consists of representatives of all the provinces, the majority of provinces agree with the SSD approach. Due to the lack of sulphate water quality guidelines in other jurisdictions, it would be easier for the other provinces of the CCME to adopt the sulphate guideline if it was derived using an SSD approach. Use the SSD approach to derive the sulphate guideline as recommended by the CCME and presented in Elphick et al. (2011) instead of the safety factor approach. Although the value may not change substantially, it is the preferred and widely accepted approach.	See comment 31. The SSD is still in the test phase and is not endorsed by BC. The CCME or other provinces can adopt or adapt the guideline if they desire.
Liam Mooney	Cameco Corporation	29/19-27	73	Include a summary of the findings of the studies described in Section 10.2. Summarize the findings of the studies presented in Section 10.2 so that it is consistent with what is presented in 10.1	The data in Section 10.2 is summarized in Appendix A. The findings in Section 10.1 describe what was published in Elphick et al. (2011).
Liam Mooney	Cameco Corporation	30/3-4	74	Concentrations should be measured to verify exposure. Include a sentence on the importance of presenting measured concentrations that verify exposure.	We agree. In order for data to be classified as primary, concentrations need to be measured at a minimum at the beginning and end of the exposure. We will include a sentence explaining the importance of presenting measured concentrations.
Liam Mooney	Cameco Corporation	30/4-5	75	What were the control concentrations (zero concentration)? Does this represent what would be in reference areas? Provide the range of sulphate concentrations present in the control treatments and note if these are similar (or not) to ambient reference areas.	We have changed the sentence in the guideline to read "Experiments from all 3 groups of studies had control concentrations that were not 0 mg/L sulphate". This speaks to the issue that the "control" didn't really have a 0 dose of sulphate because changing water hardness changed sulphate levels. See comment 15.
Liam Mooney	Cameco Corporation	30/10-11	76	Does the raw data include measured concentrations? State if the guideline is derived based on nominal or measured concentrations.	The guidelines are based on measured concentrations.
Liam Mooney	Cameco Corporation	32/4-5	77	Provide rationale for the exclusion data that was completed at only one hardness level. This data is still likely valuable for deciding if species are sensitive at a particular hardness. Consider including data with one hardness level or provide the scientific rationale for the exclusion of this data.	We were interested in looking at the effects of water hardness on the toxicity of sulphate to different species. We were looking for data that was available over a range of hardness.
Liam Mooney	Cameco Corporation	32/1	78	Section 11.0 includes very detailed methods of how the data used to derive the guideline was assessed, including assessments that were completed but not used in the final derivation of the guideline. The technical appendix should only include the methods used to derive the sulphate water quality guideline as presented. Remove any extraneous statistical details that were not used in the final derivation of	We feel that it is important for people reviewing the guidelines to understand how the data was analyzed. We provide additional details in the Appendices to the guidelines for those that want the more detailed analysis.

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				the data used to derive the guideline. These extra details could be included in an appendix.	
Liam Mooney	Cameco Corporation	32/1	79	Were nominal or measure concentrations used in the statistical analysis of the data? Include if the statistical analysis was conducted on nominal or measured concentrations.	<a href="#">The statistical analyses for the guidelines were conducted on measured concentrations.</a>
Liam Mooney	Cameco Corporation	39/8	80	The EOD (extrapolation outside the dataset) or endpoints presented as < the lowest concentration or > the highest concentration are still valuable when interpreting the toxicity testing results. However, the results cannot be used to derive guidelines. Include the actual results as supplementary information instead of EOD.	<a href="#">While an extrapolated value could be provided, the usefulness of these values is very doubtful when the extrapolated value is well outside the data range. Small changes in the dataset and/or models can lead to large changes in the estimate.</a> <a href="#">It is more defensible to state that the estimates are far outside the range of the data and so should not be trusted.</a>
Liam Mooney	Cameco Corporation	43/20-22	81	Why is a factor of two applied? Explain why a factor of two was chosen as a safety factor and the rationale for applying a safety factor.	<a href="#">See comment 64.</a>
Liam Mooney	Cameco Corporation	44/11-12	82	What is the confidence in the guideline presented when there are so many research needs? Include rationale as to why there is confidence in the guideline despite the many research needs presented.	<a href="#">Guidelines are developed based on the best available science at the time of development. This comment highlights the importance of including uncertainty factors.</a>
Liam Mooney	Cameco Corporation	45/11-13	83	What process will be used to incorporate new data or to update the guideline? Include the process by which the BCMOE will update the sulphate guideline based on new data or research findings and how the BCMOE will communicate this to stakeholders and allow for revisions to be reviewed.	<a href="#">BC periodically updates guidelines using the methods outlined in our protocol (see Derivation of Water Quality Guidelines to Protect Aquatic Life in British Columbia posted on our website). Draft guidelines are posted to our website for external review and comment prior to being approved.</a>