Appendix 5.3.3A
Cadmium Site Performance Objective for Davidson Creek

TECHNICAL MEMO

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From: Robert Goldblatt

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Subject: Cadmium site performance objective for Davidson Creek (Blackwater Gold Project)

1. Introduction

The Blackwater Gold Project (the Project) is located approximately 112 km southwest of Vanderhoof, BC. The receiving environment for the Project includes Davidson Creek, a high gradient (~5%), headwater stream. This memorandum proposes a site performance objective for cadmium (Cd) for receiving watercourses (Davidson Creek) downstream of the proposed project footprint.

The BC working guideline for Cd is based on toxicity data for cladocerans (water fleas), which are planktonic crustaceans. Davidson Creek has no lentic habitat, and therefore it will host an aquatic community that is absent of planktonic species. In this regard, cladocerans will not be present in Davidson Creek. Therefore the generic water quality guideline will likely be overprotective for Davidson Creek and development of a site performance objective (SPO) for Cd is warranted. An SPO can be defined as a limit that is protective of the most sensitive use of the water body under consideration. For Davidson Creek, the most sensitive user with regards to Cd will be aquatic life. Accordingly, the Cd SPO developed herein will be protective of aquatic organisms from chronic toxicity. An SPO is developed using the same methods as a site specific water quality objective (WQO), but differs from a WQO in that it has not been approved by the Minister of Environment.

2. Cadmium Guidelines

The British Columbia working water quality guideline (WQG) for Cd was adopted from the CCME interim Cd guideline (CCME, 1996). The CCME interim WQG was derived from the lowest published aquatic toxicity endpoint, which was a lowest observable effect level (LOEL) to reproduction of the cladoceran *Daphnia magna* over a 21 day test period (Biesinger and Christensen, 1972). A safety factor of 0.1 was applied to this LOEL of 0.17 µg/L at a hardness of 48 mg/L as $CaCO_3$. The guideline was supported by toxicity data for other cladocerans, although given an interim status chiefly because Cd levels were not verified in the *D. magna* test.

The CCME interim guideline incorporates water hardness as a modifying factor of cadmium toxicity. The hardness dependent slope used in the CCME guideline was derived from acute toxicity data for cladocerans tested at various hardness levels. At the time the CCME guideline was derived, there were insufficient chronic toxicity data to derive a relationship between chronic toxicity and hardness. Instead, the interim CCME guideline assumes that the cladoceran acute toxicity-hardness relationship is applicable to other freshwater organisms and to chronic toxicity.

The BC working guideline is lower than guidelines from other jurisdictions developed subsequent to the CCME interim guideline (USEPA, 2001; IAC, 2011; and CCME, 2012) (Figure 1). The guidelines developed after the interim CCME guideline are based on a larger chronic toxicity data set, a more diverse taxonomic data set, and hardness slopes that are derived from chronic toxicity data rather than acute toxicity. In general, the subsequent guidelines are based on a more scientifically critical evaluation of the cadmium aquatic toxicity literature.

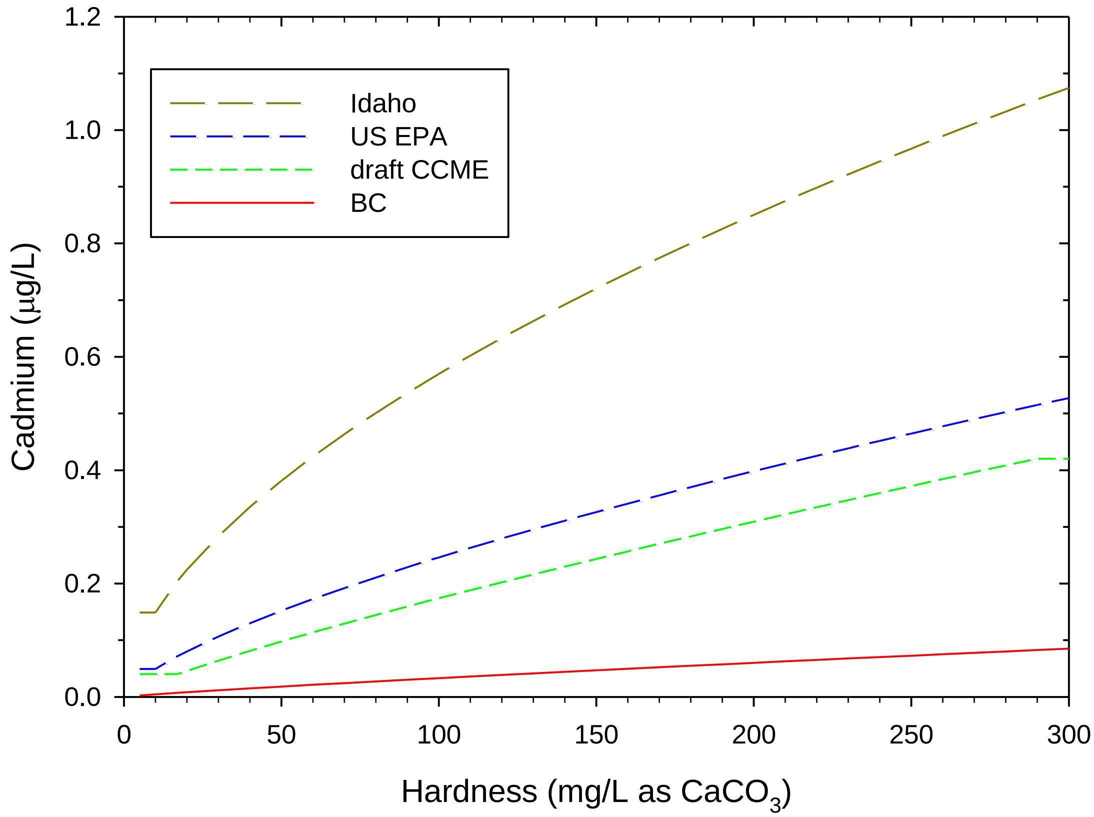

Figure 1 Comparison of long term (chronic) guidelines for cadmium in BC, Canada (draft), the United States (US EPA), and the state of Idaho.

3. Site Specific Cd Guideline for Davidson Creek

Generic water quality guidelines in B.C. are developed for the protection of all life stages of all aquatic life (*i.e.*, the zero-risk approach to establishing water quality guidelines). Local environmental conditions can make the generic guideline over- or under-protective. For example, the most sensitive species represented in the toxicological data set used to derive the generic guideline may not be present at the site of interest. Further, a substance may be more or less toxic in site water than it is under the range of conditions that are represented in the toxicological data set, due to factors that modify toxicity such as pH, water hardness, or complexing agents (*e.g.* dissolve organic carbon). Under these circumstances, it might be warranted to modify the generic criteria to account for site-specific conditions.

BC Ministry of Environment (MOE) recommends four methods for deriving site specific water quality objectives (MacDonald, 1997). Of the four methods described in MacDonald (1997), the recalculation procedure is applicable to Davidson Creek and does not require additional toxicity testing. The recalculation procedure derives an SPO using the same methodology used to derive the generic guideline, after omitting toxicity data for species which do not inhabit the waterbody under consideration. For Davidson Creek, an SPO can be derived from Cd toxicity data after omitting data for species that only inhabit lentic environments. Since the hardness-toxicity relationship used for the generic BC working Cd guideline was based on limited, acute toxicity data, derivation of an SPO will also include a reassessment of the hardness-chronic toxicity relationship, based on studies published after 1996.

3.1 Endpoint

Toxicity tests of cladocerans and amphipods have produced the most sensitive Cd toxicity endpoints in the literature. These organisms only inhabit lentic environments, and therefore the toxicity data for these organisms are not representative of the Davidson Creek community. After omission of these data, the most sensitive organism in the toxicity data sets compiled by USEPA (2001), Mebane (2010), and CCME (2012) is rainbow trout (*Oncorhynchus mykiss*). These data sets include a larger number of studies and broader taxonomic range than was available when the CCME (1996) interim guideline was derived.

The most sensitive rainbow trout endpoint is a 96-h LC50 of 0.38 µg/L at hardness 30.2 mg/L (Stratus Consulting, 1999, reported in Table 1a of USEPA, 2001). This value is much lower than the species mean acute value for rainbow trout of 1.49 µg/L at the same hardness (Mebane, 2010). The use of an unusually low endpoint for this species in the recalculation procedure is in line with the zero risk approach to setting guidelines in B.C. The use of an acute endpoint for developing a chronic SPO would be unusual for most species; however, long term toxicity tests using salmonids have produced acute toxicity rather than chronic effects. That is, long term Cd toxicity tests using salmonid fry have produced mortality that occurred in the first 4–5 days (an acute endpoint) and fish that survived this acute phase (the first 5 days) usually survived in the tested concentrations for several more weeks without any chronic effects such as reduced size or deformities (Mebane, 2010).

3.2 Hardenss-Toxicity Slope

A hardness-toxicity slope of 0.86 was derived for the 1996 CCME interim guideline from acute toxicity data, and the chronic guideline assumed that the toxicity-hardness relationship was the same as for acute toxicity. The USEPA (2001) and Mebane (2010) each developed separate acute and chronic toxicity-hardness slopes and found that the chronic slope was flatter than the acute slope (Table 1). The draft CCME guideline recently (October, 2012) posted for public review also derived a flatter slope for chronic toxicity than for acute toxicity. All slopes in Table **1** were derived following the method of Stephan *et al*. (1985). The differences in slope are primarily due to the data available at the time they were derived and the screening of the data (that is, the scientific evaluation of which data were acceptable for use in deriving a hardness-toxicity relationship).

Table 1
Hardness - toxicity slopes derived by different agencies.

Acute slope	Acute slope	# of species	Chronic slope	# of species
CCME (1996)	0.86	1[+]	assumed equal to acute	
USEPA (2001)	1.0166	12	0.7409	3
Idaho (2010)[++]	0.8403	11	0.6247	7
draft CCME (2012)	1.016	13	0.83	7

\+ CCME (1996) states toxicity data for cladocerans were used, but doesn't say how many cladoceran species were tested.

++ The guidelines developed in Mebane (2010) were adopted by the state of Idaho and approved for that state by the USEPA in 2011.

The draft CCME slope was used to derive the SPO for Davidson Creek. While it is recognized that this is a draft guideline which may change, the slope was derived using the most recent compilation of Cd chronic toxicity data. The effect of slope selection on the SPO is illustrated in (Figure 2). The different slopes make little difference to the SPO in soft to moderately hard water. As hardness increases, however, the flatter slopes derived by the USEPA and Idaho produce a noticeably lower Cd value than the CCME slope. While using the USEPA or Idaho slopes would produce a more conservative SPO, the use of the most up to date data set (CCME, 2012) is justified. As well, there is considerable conservatism in the proposed SPO due to the safety factor applied in the recalculation procedure, discussed below.

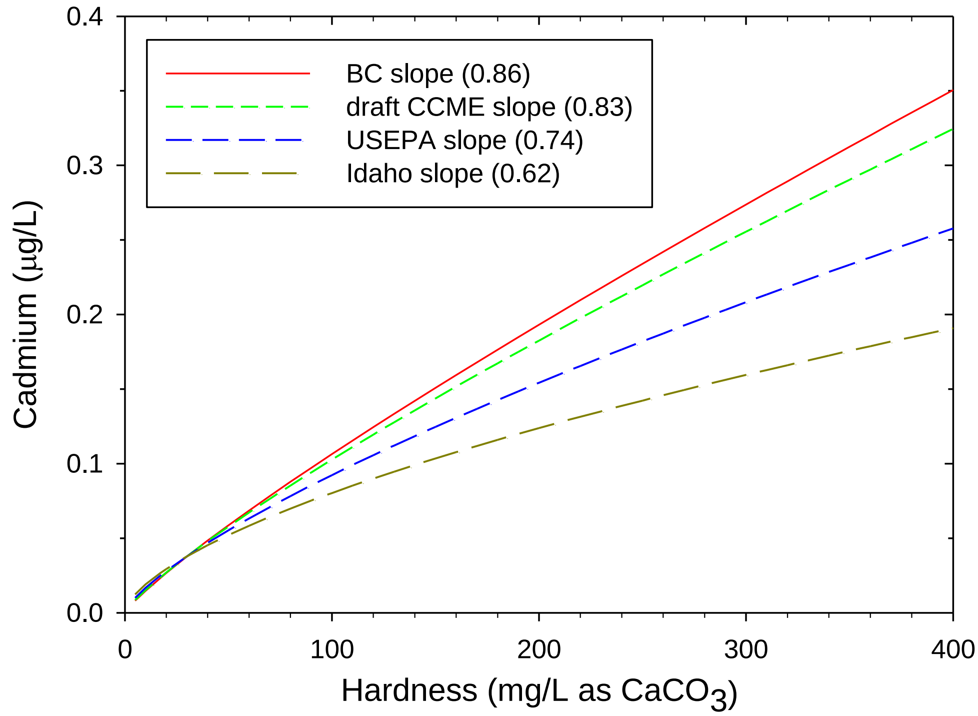

Figure 2 Effect of hardness-dependent slope on recalculation of the BC working guideline for Cd.

3.3 Safety Factor

British Columbia WQGs for the protection of aquatic life are derived by applying a safety factor to the lowest reliable toxicity endpoint. Safety factors used to derive BC WQGs vary from substance to substance, typically between 0.1 and 0.5. The magnitude of the safety factor applied is decided based on data quality and quantity, toxicity of the contaminant, severity of toxic effects, and bioaccumulation potential (Meays, 2012).

The BC working guideline for Cd applied a safety factor of 0.1. The quantity, quality, and taxonomic diversity of the Cd toxicity data set have increased dramatically since the derivation of the CCME interim guideline. The more complete data set affords less uncertainty with regards to the lowest reliable endpoint to ensure environmental protection. Despite the more reliable data set, a more conservative safety factor of 0.1 was retained in the derivation of the SPO for Davidson Creek.

3.4 Davidson Creek SPO

Using the lowest applicable endpoint (Section 3.1), the hardness dependent slope of the most recently derived toxicity-hardness relationship (Section 3.2), and a safety factor of 0.1 (Section 3.3), the BC working guideline for Cd can be recalculated for Davidson Creek as:

$$\text{SPO } (\mu g/L \text{ Cd}) = 0.1 * 10^{(0.83[\log(\text{hardness})] - 1.649)} \quad \text{Eq. 1}$$

The SPO is shown in comparison to the BC working guideline and the draft CCME guideline in Table 2 and Figure 3. The SPO is higher than the BC working guideline, but approximately half of the draft CCME guideline. Comparing the SPO to all chronic toxicity endpoints and rainbow trout acute toxicity endpoints compiled by Mebane (2010) shows that the SPO is protective of all aquatic life, including the lentic species omitted as part of the recalculation procedure.

Table 2
Cadmium SPOs for Davidson Creek at different hardness levels compared to water quality guidelines.

Hardness (mg/L as $CaCO_3$)	Davidson Ck. SPO (µg/L)	BC guideline (µg/L)	draft CCME guideline (µg/L)
50	0.06	0.02	0.10
100	0.10	0.03	0.18
200	0.18	0.06	0.32
300	0.26	0.09	0.42

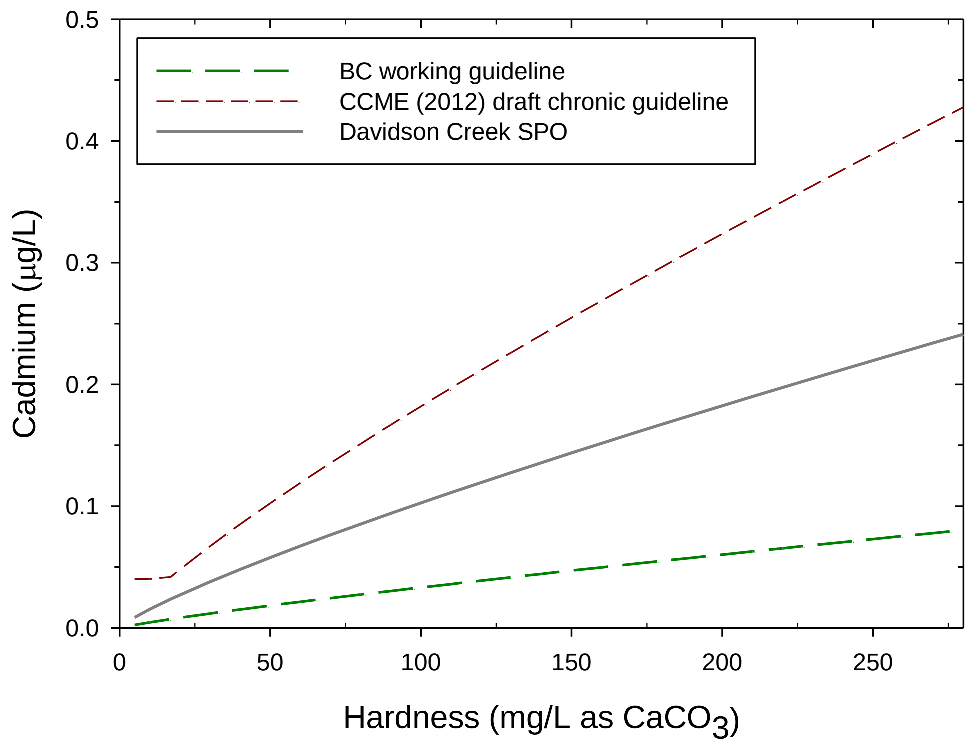

Figure 3 Comparison of proposed SPOs to current and draft guidelines.

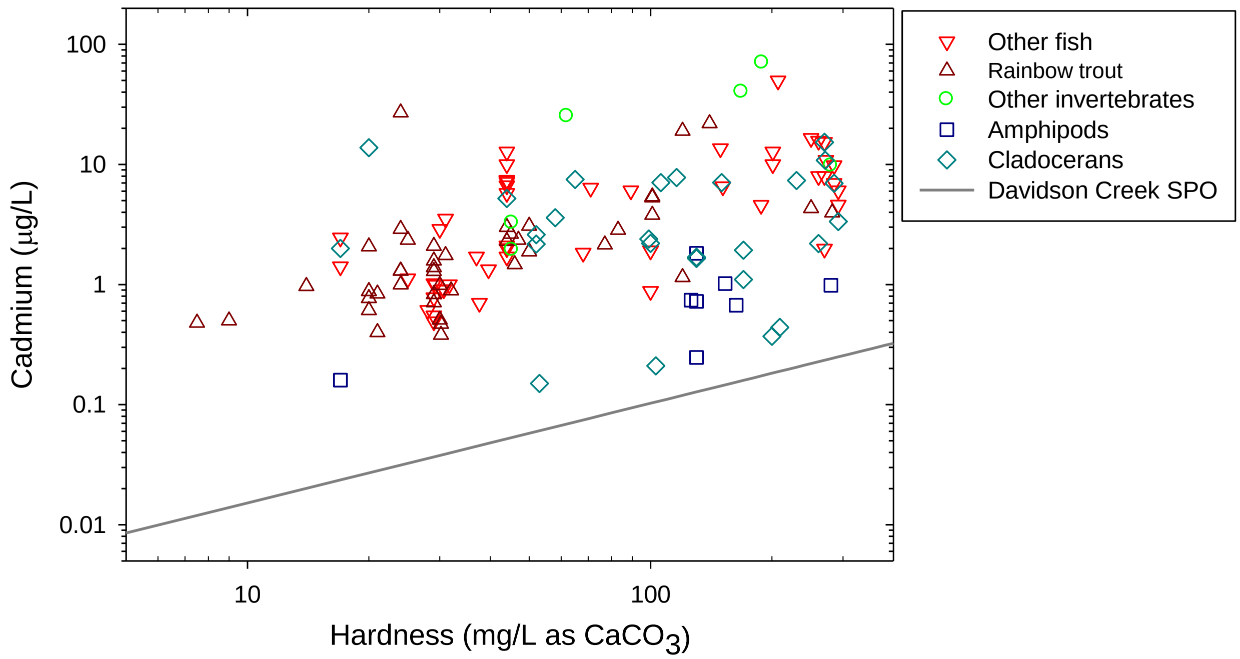

Figure 4 Comparison of Davidson Creek SPO to chronic values compiled in Table 16 of Mebane (2010).

4. References

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