Appendix C

File: PE 107517 – Lake Koocanusa Working Group

Date 20 October 2017

Mike Sokal, Impact Assessment Biologist, ENV
102 Industrial Place, Penticton
BC V2A 7C8

Dear Mike,

RE: Selenium Loading to Lake Koocanusa

This memo, and the analysis and results presented here-in, were prepared in response to a request by the Lake Koocanusa Working Group (LKWG) for an estimate of, and comparison between, selenium (Se) loadings discharged to Lake Koocanusa from the Elk River and Kootenay River. This information is of interest to the LKWG as regional context of relative Se loading rates to Lake Koocanusa from the five coal mines operated by Teck Coal Limited (Teck) in the Elk River watershed compared with all other regional Se loadings to the lake ("background" loadings). This information and analysis includes several assumptions, discussed in the following text, and is intended to support environmental impact and management discussions within the working group. The analysis was also conducted using only 2015/2016 data to provide a snapshot of current Se loading conditions.

Analysis

Both water quantity (m^3/s) and Se concentration (ug/l) are required to calculate Se load (mass). Ideally, water quantity and Se concentration would be measured concurrently and at the same location to minimize uncertainty in calculated load. Water quantity data recorded by the Water Survey of Canada in the Elk River at Fernie and the Kootenay River at Fort Steele were selected for use in the calculations, as they represent active water quantity monitoring stations on their respective rivers nearest to both Lake Koocanusa and available Se concentration data. Selected Se concentration data were recorded by Teck in the Elk River at Elko and jointly by Environment Canada and the Province of British Columbia in the Kootenay River at Fenwick. Metadata for each of these monitoring locations is summarized in Table 1.

Ministry of Environment and Climate Change Strategy
Mining Operations
Environmental Protection Division
Mailing Address:
401-333 Victoria Street
Nelson, B.C.
V1L 1G2
Telephone: 250-354-6358
Facsimile: 250-354-6332
Website: www.gov.bc.ca/env

Table 1: Monitoring Location Metadata

Station Name/Location	Station ID	Data Used	Location		Watershed	Drainage Area Adjustment	
			Latitude	Longitude	Area (km^2)	Value	Description
Elk River at Fernie	08NK002	Water Quantity	49°30'12" N	115°04'12" W	3,090	1.15	Scale Water Quantity to Elko
Elk River at Elko	08NK001/E294312	Se Concentration	49°16'50" N	115°05'55" W	3,550	-	
Kootenay River at Fort Steele	08NG065	Water Quantity	49°36'43" N	115°38'07" W	11,500	1.03	Scale Water Quantity to Fenwick
Kootenay River at Fenwick	08NG0009	Se Concentration	49°31'40" N	115°32'57" W	11,850	1.39	Scale "Background" Se Load to Border
Kootenay River at Newgate (Canada/US Border)	08NG042	Watershed Area	49°00'52" N	115°10'27" W	20,000		"Background" area is 16,450 km^2

Prior to calculating Se load, the water quantity data were adjusted to the applicable Se concentration measurement location to account for additional inflows to the rivers between monitoring locations. This adjustment was accomplished by scaling the water quantity data by the difference in drainage area between the monitoring locations, the values of which are presented in Table 1. This adjustment method inherently assumes that the flow per unit watershed area (i.e. $m^3/s/km^2$) is the same upstream and downstream of the water quantity monitoring location. While there is likely to be some difference in the actual flow per unit watershed area, this adjustment is considered reasonable given both the proximity of the quantity and concentration measurement locations (i.e. small adjustment values), and the comparative purpose of the analysis. Only the quantity data recorded nearest in time to the concentration data were used in the analysis, with the discrepancy in timing between all quantity and Se concentration measurements being less than one day.

All five Teck coal mines in the Elk Valley are all located upstream of Elko, and therefore the Se load values for the Elk River at Elko are representative of total Se contributed to the system from the mines; however, the Fenwick values are only representative of the Kootenay River watershed upstream of Fenwick, not of the entire "background" watershed area contributing to Lake Koocanusa. To adjust the results to be representative of the total "background" contributing area, the Se load values were also scaled by the relative difference in "background" watershed area between Fenwick and Lake Koocanusa at the Canada/US border. This is a simplifying assumption but is considered reasonable given the comparative purpose of the analysis and the similar monitored Se concentrations within the Kootenay River watershed, as shown on Figure 1. The Wardner Se concentrations are nearly identical and the station is nearer to the inlet of Lake Koocanusa than Fenwick, and is downstream of the Bull River but upstream of Kikomun Creek, which has anomalously high Se concentrations. Exclusion of the Kikomun Creek Se load isn't expected to meaningfully alter the results and conclusions of the analysis, as its watershed is only 0.4% of the total "background" watershed of Lake Koocanusa. Considering the relative size of the creek and the Se concentrations presented on Figure 1, Se load in Kikomun Creek likely contributes less than 4% additional "background" Se load to Lake Koocanusa, which is within the range of uncertainty of this analysis (see Result and Discussion Section for more details on uncertainty).

In addition to calculating Kootenay River "background" and Elk River Se load for each concentration measurement, the daily mean Se load was also calculated for each set of values. To minimize potential bias associated with differences in the timing and number of samples, mean daily load was calculated using only "concurrent" values. The discrepancy in timing of concurrent values was up to two weeks during the less frequently monitored August through February period, and 1-2 days during the more frequently monitored March through July period.

Figure 1: Se concentrations measured August 17, 2016

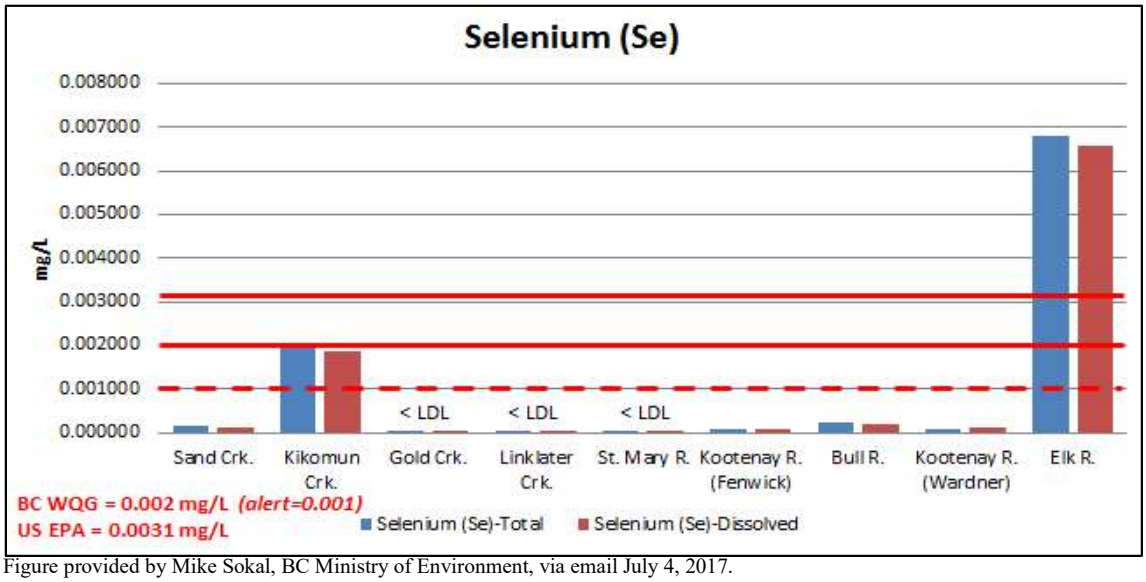


Figure provided by Mike Sokal, BC Ministry of Environment, via email July 4, 2017.

Results and Discussion

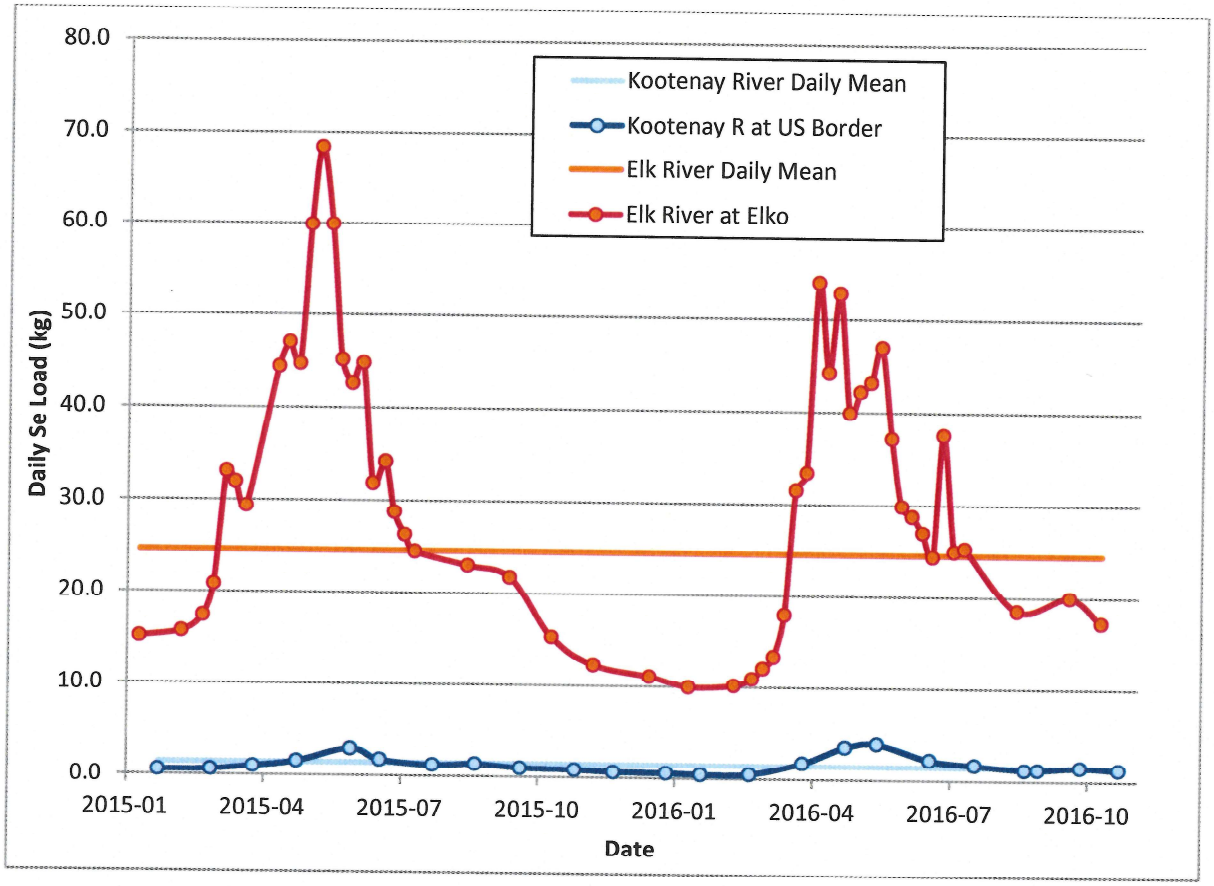
All calculated Se loading results are presented below in Figure 2. The figure provides a comparison between Se loadings (kg/day) to Lake Koocanusa from the entire "background" Kootenay River watershed above the Canada/US border, and the Elk River at Elko, for each Se concentration sample date in 2015 and 2016 as well as the concurrent mean Se daily load.

The results clearly show that Se loadings to Lake Koocanusa are dominated by the Elk River. On average during 2015-2016, the Elk River contributed approximately 17 times more Se to the lake than did the entirety of the remaining Kootenay River watershed. This result also makes sense intuitively; the "background" Kootenay River watershed at the border is approximately 4.5 times larger than the Elk River at Elko, a relationship that can be used to approximate the relationship between mean water quantity, but the mean concentration of Se is approximately 80 times lower. Therefore it would be expected, as proven out by this analysis, that Se load should be in the range of 17 (~ 80/4.5) times lower in the Kootenay River than the Elk River.

As discussed in the Analysis section, the results incorporate several assumptions that add to the overall uncertainty. The magnitude of uncertainty in the analysis was assessed by varying the water quantity and load scaling assumptions as follows:

- Water quantity and Se load (Kootenay River only) generated from the scaled portion of the Kootenay and Elk River watersheds was half of the upstream monitored value, and
- Water quantity and Se load (Kootenay River only) generated from the scaled portion of the Kootenay and Elk River watersheds was 50% greater than the upstream monitored value.

Figure 2: Lake Koocanusa Se Loading Results



The resultant uncertainty is less than +/- 20% for the Kootenay River Se load values at the Canada/US border, and less than +/- 10% for the Elk River Se load values at Elko. The magnitude of the uncertainty is two orders of magnitude less than the difference between the Kootenay and Elk River Se loading results, and as such there is very high confidence in the conclusion that Se loading to Lake Koocanusa is primarily driven by loading from the Elk River.

I trust that this memo meets the Lake Koocanusa Working Groups needs for a comparison of Se loadings to Lake Koocanusa from the Elk and Kootenay Rivers. Please address any questions or comments to the undersigned.

Sincerely,

PROFESSIONAL
PROVINCE OF
K. T. C. TERRY
39897
BRITISH COLUMBIA
GEOSCIENTIST

Kyle Terry, P.Geo.
Hydrologist