CANADA-BRITISH COLUMBIA WATER QUALITY MONITORING AGREEMENT

WATER QUALITY ASSESSMENT OF THE MOYIE RIVER AT KINGSGATE (1990 – 2007)

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EXECUTIVE SUMMARY

The Moyie River is located in southeast B.C. and drains into the Kootenai River in Idaho before re-entering B.C. as the Kootenay River. The watershed is used for fishing, recreation, irrigation, and domestic and municipal water uses. Forestry and some agriculture are the main anthropogenic influences. The hardness in the Moyie River is typically low which suggests that it would be sensitive to metals that might be discharged (even at low levels) should mining occur in the basin.

This report assesses 11 years of water quality data from the Moyie River at Kingsgate over a period from 1990 to 2007. The water quality station is located 0.5 km upstream from the border and has an upstream contributory drainage area of 1,480 km^2. Water quality samples were collected once every two months until the station was suspended in 1995, and then collected monthly when the site was reactivated in 2003 as a federal-provincial water quality monitoring program station. Flow was monitored on the Moyie River at Eastport on the Canada-US border by the Water Survey of Canada.

CONCLUSIONS

- Moyie River water quality was generally good, with a small number of transient seasonal spikes in certain parameters that were related to increased flow and turbidity.
- Total aluminum concentrations exceeded the B.C. guidelines that are expressed as dissolved concentrations of the metal on a seasonal basis.
- Total cadmium concentrations exceeded the B.C. and CCME aquatic life guidelines during freshet, but were near or below guidelines during base-flows.
- Total iron and total lead exceeded aquatic life guidelines during freshet, but these exceedences were related to high turbidity values and not likely bioavailable.
- *E.coli* and fecal coliforms were measured since 2003 but the sampling frequency did not meet requirements for assessing guideline compliance. Although there were occasional spikes over the sample period, median values were generally low. However, visually it

appears as though *E.coli* and fecal coliform measurements were increasing over the sample period. Filtration and disinfection would be required in advance of drinking water use.

- Alkalinity measurements suggest that the Moyie River is moderately sensitive to acid inputs, and total hardness measurements classify the river as a soft water system. This suggests that the Moyie River may be sensitive to mining, should it occur within the watershed.
- A number of metals need to be measured differently if comparisons are to be made to guideline values as these exist. The metals and forms required to be measured are aluminum (dissolved and inorganic monomeric, when available), chromium (trivalent and hexavalent, when analyses are available and reliable), and iron (continue to measure total but also dissolved).

RECOMMENDATIONS

It is recommended that the Moyie River water quality monitoring station be deactivated since anthropogenic inputs are limited and water quality is typically good. Due to the break in the long-term dataset, the Moyie River serves as an appropriate surveillance site, but not as an appropriate long-term monitoring site. Also, there are numerous other long-term water quality monitoring stations in the Kootenay watershed and along the Kootenay mainstem that are used to monitor water quality across the Kootenay basin. It is suggested that this site be periodically monitored by B.C. Ministry of Environment staff, and that it be reactivated as a federal-provincial station if anthropogenic impacts become more prevalent in the watershed.

ACKNOWLEDGEMENTS

The data was reviewed by Ayisha Yeow and Shale Irwin, and a map of the Moyie River Basin was created by Jennifer MacDonald. This report was reviewed by Les Swain of Tri-Star Environmental, Andrea Ryan of Environment Canada and Jodie Frenette of the B.C. Ministry of Environment. We thank these individuals for their contributions to this document. Any errors or omission are the responsibility of the author.

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INTRODUCTION

The Moyie River watershed is located in the southeast corner of British Columbia (Figure 1). Its headwaters are in the Purcell Mountains southwest from Cranbrook. The Moyie River enters Idaho at Kingsgate and joins the Kootenai River, before re-entering B.C. as the Kootenay River[1].

The Moyie River at Kingsgate water quality monitoring station is located at the Highway 3-95 Bridge, 0.5 km upstream from the Canada-US border (Figure 1). The drainage area of the river at the water quality station is 1,480 km^2. The watershed is used for fishing, recreation, and irrigation[1], and there are water licenses including the Regional District of East Kootenay (Moyie Lake) water license. Forestry and some agriculture were cited as the main influences on water quality[2]. Highway 3-95 follows the river through the Canadian portion of the basin, and might affect water quality through the use of road salt for de-icing and spills of petroleum or other hazardous cargoes. The hardness in the Moyie River is typically low compared to similar rivers in the East Kootenay[2], and is likely more sensitive to metal pollution should mining occur in the basin (historical mining occurred along Moyie Lake).

Flow was monitored on the Moyie River at Eastport on the Canada-US border by the Water Survey of Canada (station BC08NH006), and these data are plotted in Figure 2. Environment Canada collected water quality data at Kingsgate about once every two months during 1980-95 and the data are stored on ENVIRODAT (BC08NH0010) and the B.C. Environmental Monitoring System (EMS, site number 0200099). Water quality monitoring at the station was suspended in 1995, and then reactivated in 2003 as a federal-provincial water quality monitoring station with joint operation by Canada and B.C. Water quality data were collected monthly from September 2003 to March 2009, when the site was de-activated.

This report assesses data from the most recent 18 years, from 1990 to the end of 2007. Similar time periods are compared pre- and post-activation of the monitoring program.

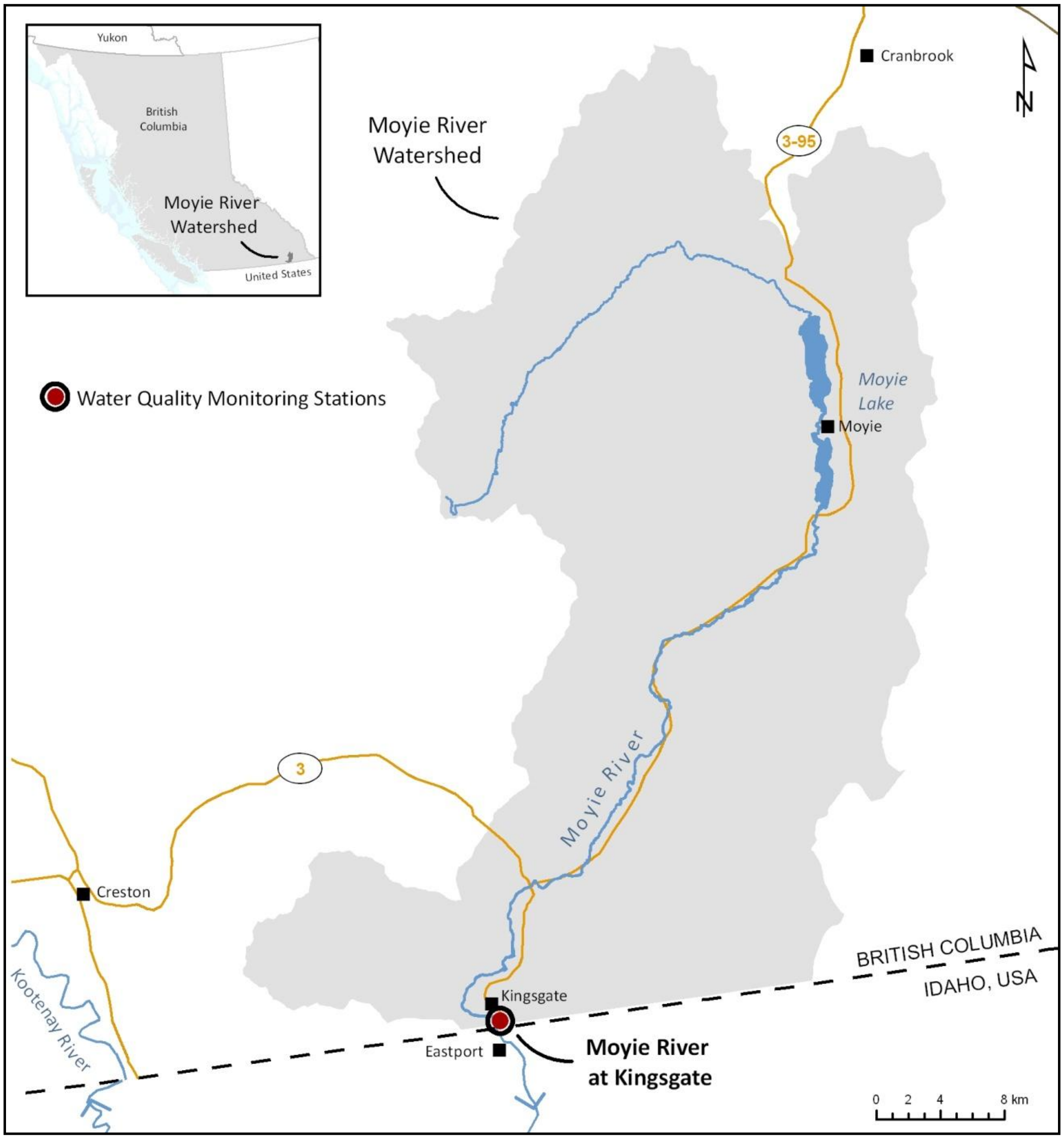


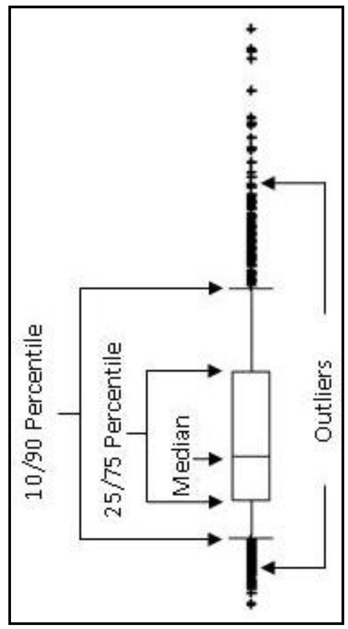
Figure 1: Map of the Canadian portion of the Moyie Watershed.

Quality Control and Quality Assurance

Efforts were taken to ensure quality control and quality assurance throughout the sample period. Duplicate or triplicate samples and field blanks were scheduled at regular intervals to assess potential sources of sample contamination and precision. The water quality results were reviewed in advance of the preparation of this report and questionable or erroneous values were removed from the dataset. Total dissolved nitrogen results were known to be contaminated from filters used in analyses and thus, this parameter was not considered in this report.

Graphs

In addition to time-series plots, box-and-whisker plots were used to compare water quality values pre- and post-site reactivation (see example on right). Box-and-whisker plots are useful since they visually display the entire statistical distribution of a dataset. The plots display central tendency (median), sample variability (inter-quartile and percentile range), and extreme results and outliers.

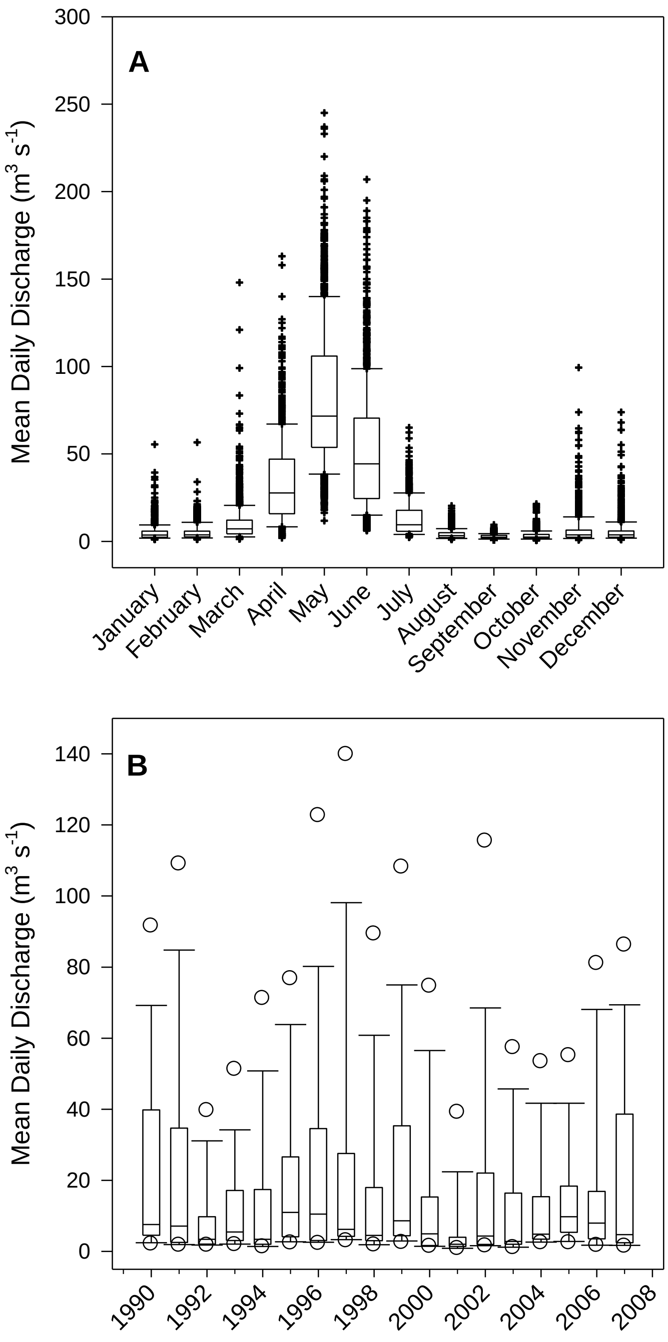


Water Quality Assessment

The state of the water quality was determined by comparing the results to the B.C. Environment's *Approved Water Quality Guidelines*[3] and *Working Guidelines for Water Quality*[4], and the *Canadian Council of Ministers of the Environment Guidelines for the Protection of Aquatic Life Guidelines*[5]. Substances listed below are not discussed further since all concentrations met guidelines, and include the following: antimony, arsenic, barium, beryllium, bismuth, boron, bromide, chloride, cobalt, dissolved calcium, specific conductivity, lithium, manganese, molybdenum, nickel, nitrogen in its different forms, phosphorus, potassium, total dissolved solids (TDS), total suspended solids (TSS), silica, strontium, sulphate, thallium, tin, vanadium and zinc.

Flow: Flow was measured continuously at the Moyie River at Eastport on the Canada-US border by the Water Survey of Canada and reported as mean daily discharge. Monthly discharge varies seasonally, with the spring freshet peaking in May, and base flows occurring from August to February (Figure 2A). This seasonal pattern in flow has a strong influence on water quality concentrations, diluting groundwater-driven parameters during freshet, and transporting greater levels of suspended sediment loads during spring melt and washout which increases total metal concentrations. The degree to which dilution and freshet occur is dependent on seasonal and annual flows, and although annual flows fluctuate (Figure 2B), there was no significant trend over time (Mann-Kendall Test, total annual discharge 1970-2007).

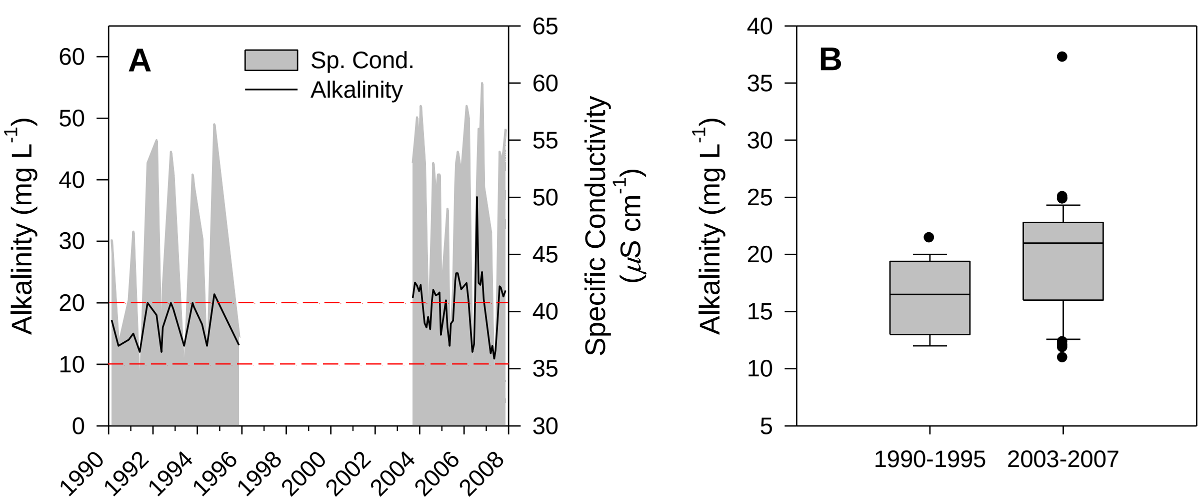
Figure 2: Monthly box-and-whisker plots of mean daily discharge from 1970 to 2007 (A) and annual box-and-whisker plots of mean daily discharge from 1990 to 2007 (B) from the Moyie River at Eastport.



Note: open circles in Figure 2B represent the 95th percentile, not outliers.

Alkalinity: Alkalinity concentrations over the sample period suggest that the Moyie River is moderately sensitive to acid inputs, although concentrations seem to have increased post site reactivation (Figure 3). The median alkalinity value increased from 16.5 mg L^{-1} (1990-1995) to 21.0 mg L^{-1} between 2003 and 2007 (Figure 3B), suggesting that the Moyie River has become less sensitive to acid inputs. It is difficult to discern the source of this change in alkalinity; it had been suggested that the change may be due to changes in surface water or groundwater patterns[2]. The relationship between mean daily discharge and alkalinity was modelled using a linear regression ($p < 0.001$, $R^2 = 0.77$, log alkalinity = 1.405 – [0.158 x log discharge]). As mentioned above, total annual discharge varies but there was no significant trend over time (1970 to 2007). Therefore, it does not seem likely that a trend in alkalinity concentrations is related to changing flow patterns; rather, the changes in alkalinity concentrations are likely an artefact of increased and consistent sampling post-reactivation.

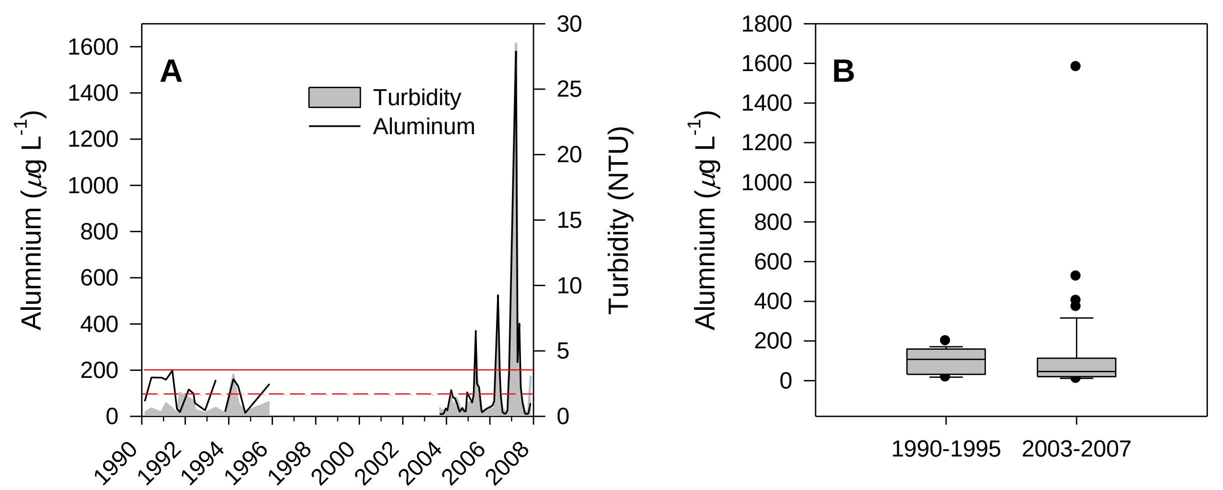
Figure 3: Total alkalinity and specific conductivity from the Moyie River from 1990 to 2007(A) and box-and-whisker plots comparing pre- and post- site reactivation alkalinity measurements (B).



Note: Dashed red line represents the lower and upper threshold for alkalinity concentrations which are moderately sensitive to acid inputs.

Aluminum: Total aluminum concentrations varied positively with flow (Spearman Correlation, r_s = 0.9) with annual maximums coinciding with freshet during late spring, and annual lows coinciding with base-flows during the fall and winter. Flow-associated seasonal spikes in total aluminum exceed the maximum B.C. aquatic life and drinking water guidelines established for dissolved aluminum of 100 μg L^{-1} and 200 μg L^{-1}, respectively (Figure 4). However, total aluminum was positively correlated with turbidity (Spearman Correlation, r_s = 0.67; Figure 4A), and thus the seasonal spikes are likely associated with suspended sediment and not bioavailable. Improved laboratory analytical techniques and changing minimum detection limits (MDLs) over the sample period suggest that total aluminum concentrations have decreased between pre- and post-reactivation periods (Figure 4B), but actual concentrations have not likely changed between these sample periods. Efforts should be made in future monitoring to measure the dissolved and inorganic monomeric forms of aluminum so that comparisons to the existing and future guidelines are possible.

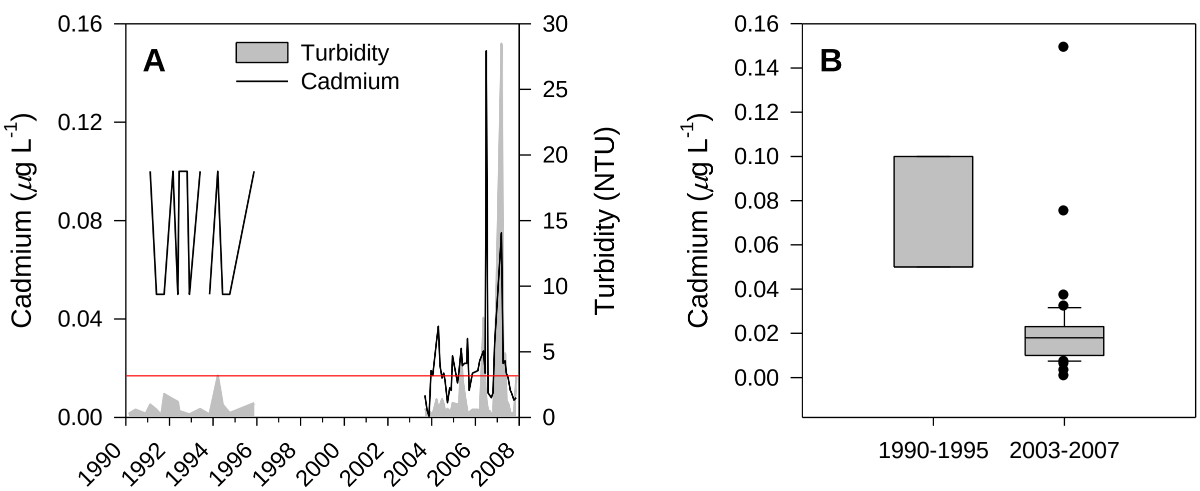
Figure 4: Total aluminum and turbidity measurements (A) and box-and-whisker plots comparing pre- and post- site reactivation total aluminum concentrations (B).



Note: Dashed red line represents the B.C. aquatic life guideline for dissolved Al and the CCME guideline for total Al; the solid line represents the B.C. drinking water supply guideline.

Cadmium: Total cadmium concentrations varied with flow (Spearman Correlation, $r_s = 0.44$) with seasonal maximums coinciding with spring freshet and seasonal minimums coinciding with base-flows. Seasonal maximums tended to exceed the B.C. and CCME guidelines for aquatic life; seasonal minimums tended to remain near or below aquatic life guidelines (Figure 5A). Two large exceedences occurred during the spring freshets of 2006 and 2007, but these transient events were associated with turbidity and the cadmium was unlikely to be bioavailable (Figure 5A). Previous reports suggest that total cadmium levels are near guideline levels due to natural mineralization within the watershed[2]. Improved laboratory analytical techniques and changing MDLs over the sample period have resulted in more frequently detected concentrations which have allowed for better concentration/guideline comparisons, but can give a false impression that concentrations have decreased over time (Figure 5B).

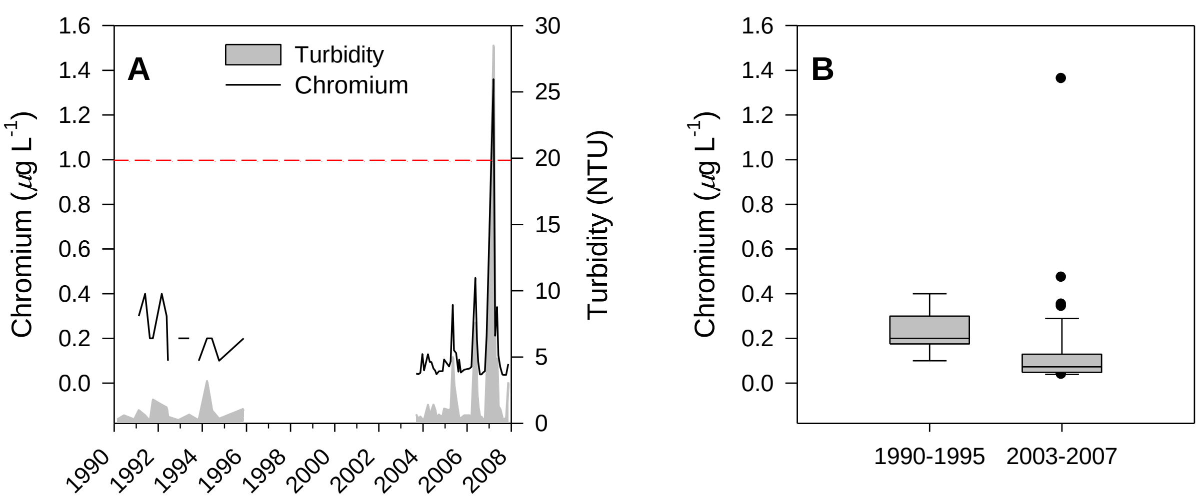
Figure 5: Total cadmium and turbidity measurements (A) and box-and-whisker plots comparing pre- and post- site reactivation total cadmium concentrations (B).



Note: The solid line represents the CCME aquatic life guideline.

Chromium: Total chromium concentrations are generally low in the Moyie River but vary seasonally with flow (Spearman Correlation, $r_s = 0.67$) and turbidity (Spearman Correlation, $r_s = 0.58$; Figure 6A). The CCME aquatic life and B.C. working aquatic life guidelines are established for Cr^{3+} (1 μg L^{-1}) and Cr^{6+} (8.9 μg L^{-1}); total chromium concentrations typically remained below these guidelines except for one major turbidity-driven exceedence in 2007 (Figure 6A). Nevertheless, total chromium concentrations were well below guidelines developed for trivalent (Cr^{3+}) and hexavalent (Cr^{6+}) chromium. Efforts should be made in any future monitoring programs to measure both forms of chromium if this metal is of concern, so that direct comparisons to the guidelines are possible.

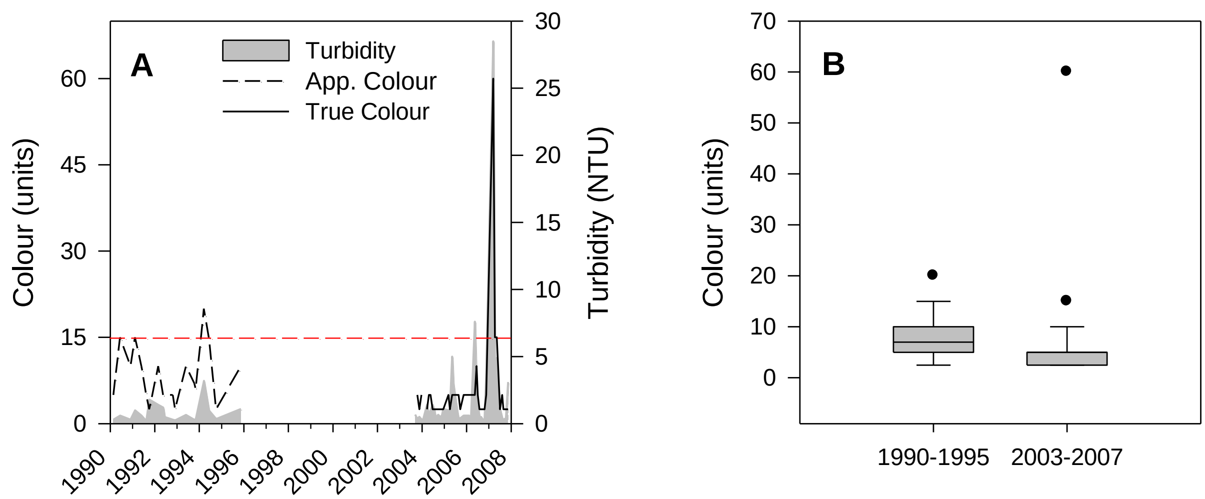
Figure 6: Total chromium and turbidity measurements (A) and box-and-whisker plots comparing pre- and post- site reactivation total cadmium concentrations (B).



Note: Dashed red line represents the B.C. working aquatic life guideline and the CCME aquatic life guideline for Cr^{3+}.

Colour: Colour, measured as apparent colour until de-activation, then as true colour after re-activation, varied seasonally with flow and turbidity (Figure 7A). Colour measurements were generally below the B.C. and the CCME aesthetic objective for drinking water of 15 true colour units (TCU). There was a recent major true colour exceedence during the 2007 freshet, but this exceedence coincided with a high turbidity value, and does not represent the general condition of the stream (Figure 7A). Data in Figure 7B suggest that colour measurements have declined between both sample periods, but this is likely due to the two different forms of colour that were reported.

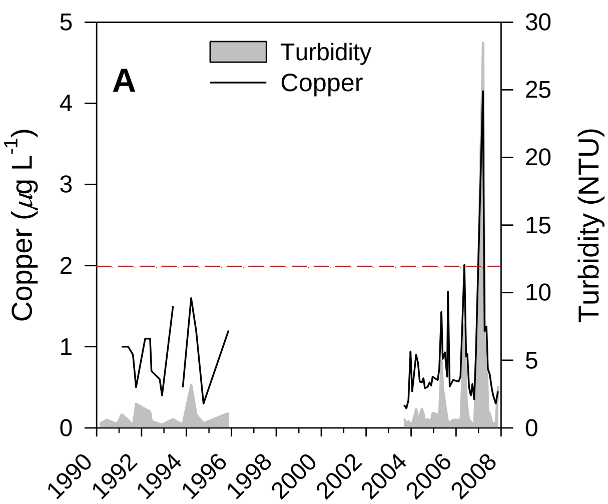
Figure 7: Apparent and true colour measurements, and turbidity measurements (A) over the sample period and whisker plots comparing pre- and post- site reactivation colour measurements (B).

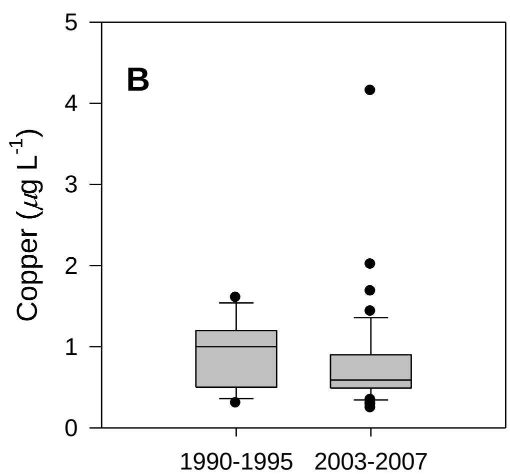


Note: Dashed red line represents the B.C. and the CCME aesthetic drinking water guideline for true colour.

Copper: Total copper varied seasonally with flow (Spearman Correlation, $r_s = 0.78$) and turbidity (Spearman Correlation, $r_s = 0.58$; Figure 8A). Total copper concentrations were typically below the B.C. and the CCME aquatic life guidelines (both guidelines are hardness-derived) except for one occasion in 2006 and another in 2007 (Figure 8A), but both of these exceedences were related to turbidity spikes and the copper therefore was not likely bioavailable.

Figure 8: Total copper and turbidity measurements (A) and box-and-whisker plots comparing pre- and post- site reactivation total copper concentrations (B).

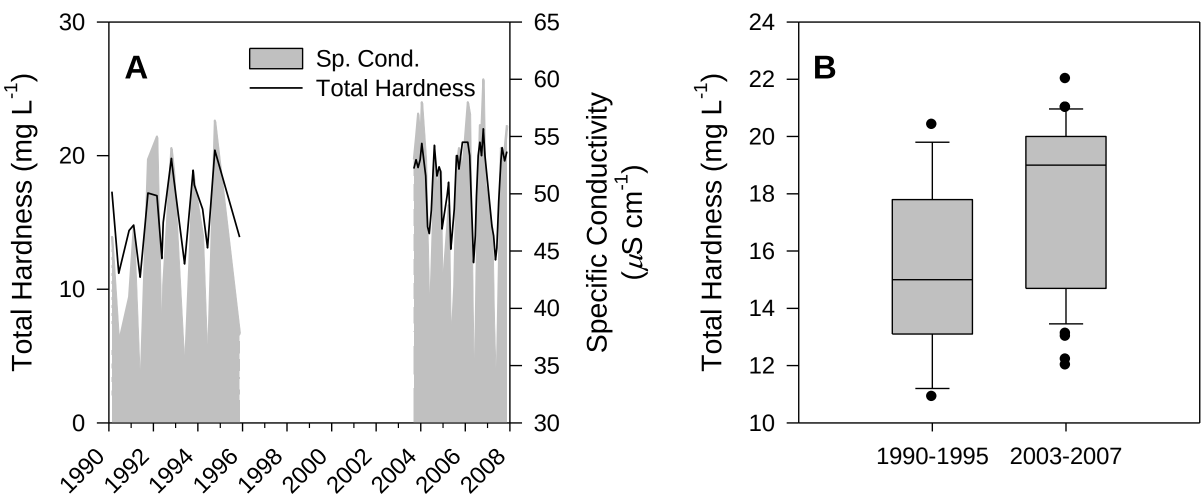




Note: Dashed red line represents the B.C. and the CCME aquatic life guideline for total copper.

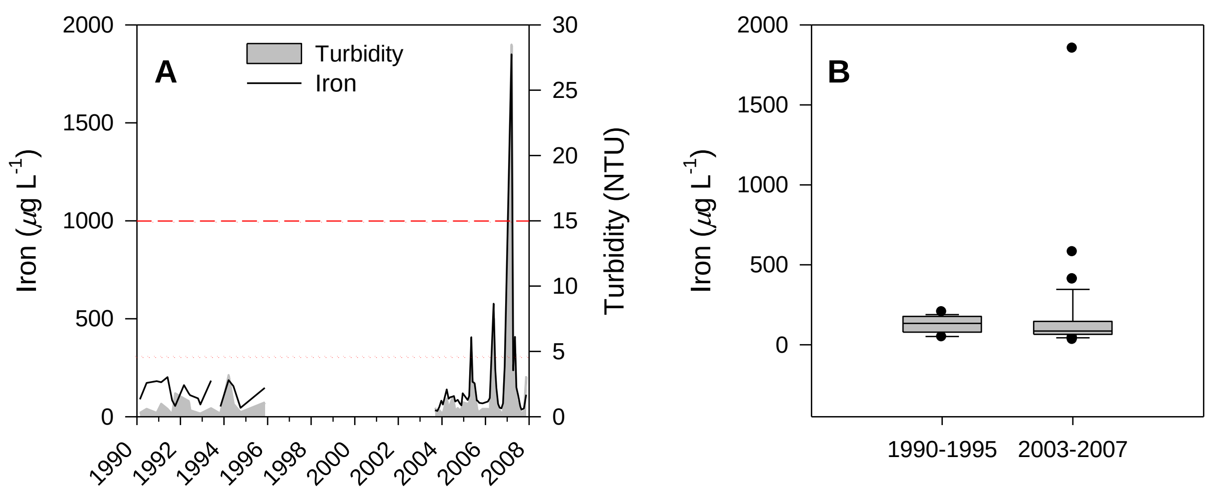
Hardness: Moyie River water can be classified as soft based on the total hardness concentration, which ranged from 11 to 22 mg L^{-1} over the sample period (Figure 9A). Recent total hardness results suggest that measurements are increasing (Figure 9B). Similar to alkalinity, total hardness was modelled with mean daily discharge using linear regression ($p < 0.001$, $R^2 = 0.77$, total hardness = 21.65 – [4.717 x log discharge]). Therefore, this suggests that the change in total hardness is an artefact of an increase in sample frequency and consistency since 2003, like that of alkalinity. Nonetheless, total hardness measurements were fairly low relative to other systems in the East Kootenays[2]; low total hardness is known to affect (i.e. increase) the toxicity of a variety of metals such as copper and lead.

Figure 9: Total hardness and specific conductivity measurements (A) and box-and-whisker plots comparing pre- and post- site reactivation total copper concentrations (B).



Iron: Total iron concentrations varied seasonally with flow (Spearman Correlation, r_s = 0.87) and turbidity (Spearman Correlation, r_s = 0.7; Figure 10A). Total iron concentrations were generally well below the B.C. and the CCME aquatic life guidelines of 1000 μg L^{-1} and 300 μg L^{-1}, respectively. Although turbidity-driven spikes can temporarily exceed the CCME and the B.C. guidelines, these transient events do not pose a danger to aquatic organisms and are typical of the annual flow pattern. Pre- and post-site reactivation total iron concentrations do not appear to have changed (Figure 10B). Efforts should be made in any future monitoring programs to measure both total and dissolved forms of iron so that comparisons to the guidelines are possible.

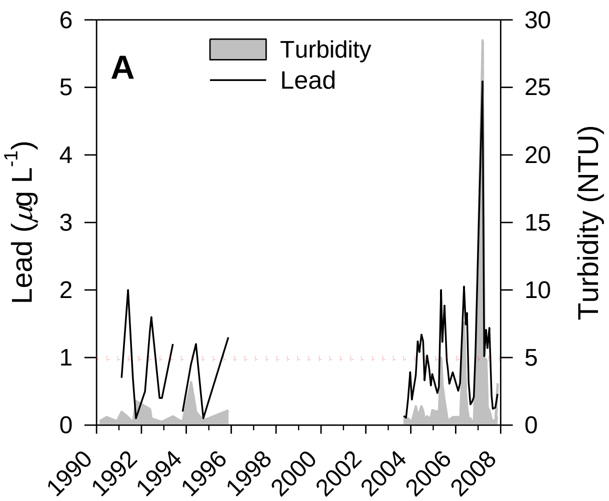
Figure 10: Total iron and turbidity measurements (A) and box-and-whisker plots comparing pre- and post- site reactivation total iron concentrations (B).

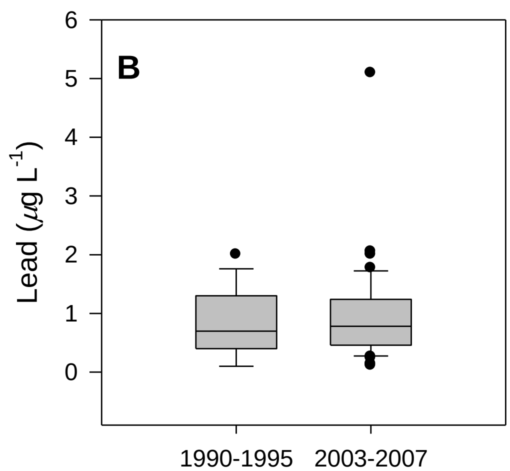


Note: Dashed red line represents the B.C. aquatic life guideline and the dotted red line represents the CCME aquatic life guideline for total iron.

Lead: Total lead concentrations varied seasonally with flow (Spearman Correlation, $r_s = 0.87$) and turbidity (Spearman Correlation, $r_s = 0.61$; Figure 11A). Seasonal maximums tend to exceed the CCME guideline for total lead for soft water systems, but do not exceed the B.C. hardness-derived instantaneous guideline for aquatic life which ranged from 5 to 12 μg L^{-1} over the sample period. Since these seasonal exceedences are related to turbidity, the lead was likely bound to particulate matter and not bioavailable. Comparisons of concentrations measured prior to site deactivation and after reactivation suggests that total lead levels have not changed (Figure 11B).

Figure 11: Total lead and turbidity measurements (A) and box-and-whisker plots comparing pre- and post- site reactivation total lead concentrations (B).

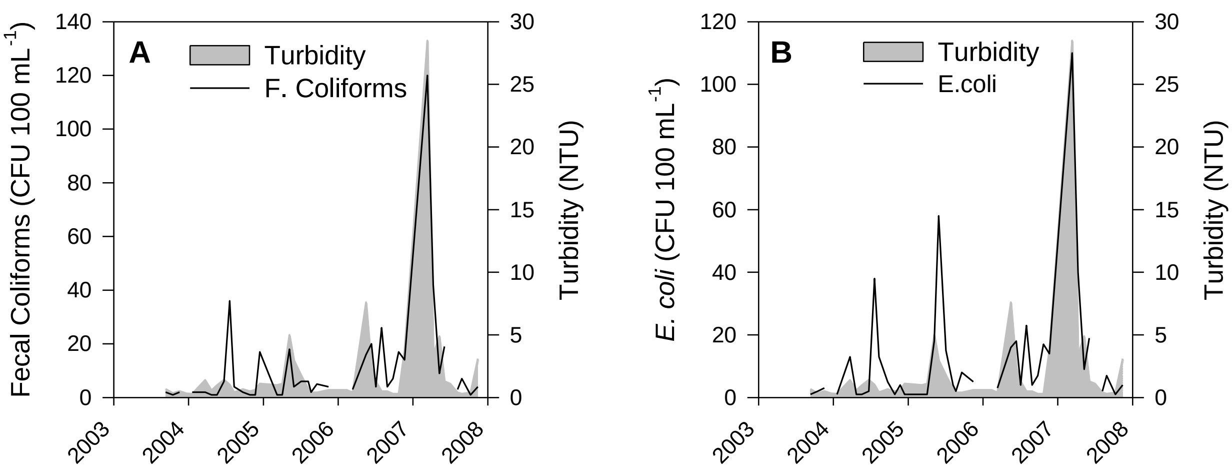




Note: Dotted red line represents the CCME aquatic life guideline for total lead.

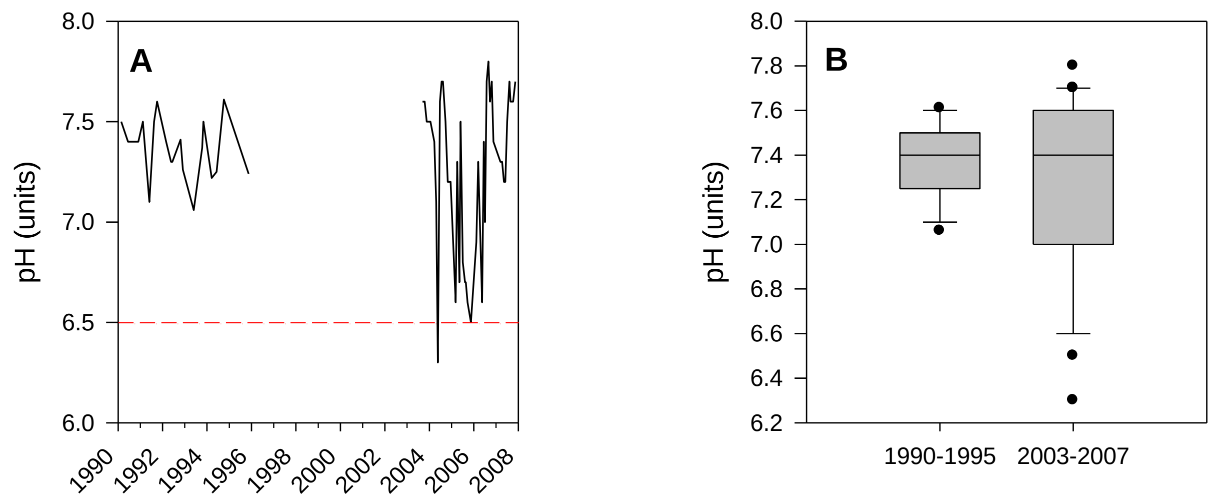
Microbiological Indicators: Fecal coliforms and *E.coli* have been measured in the Moyie River since 2003. Current B.C. drinking water guidelines for fecal coliforms and *E.coli* vary based on the level of treatment provided and are based on a statistical determination of five samples in 30 days. Direct comparisons to the guidelines cannot be made since the requirement for the sampling frequency was not met. Fecal coliforms and *E.coli* measurements were relatively low during the sample period, with a median measurement of 4 colony forming units (CFU) 100 mL^{-1} and 5 CFU 100mL^{-1}, respectively, over the sample period. There were spikes which were associated with high turbidity (Figure 12) and spring freshet; both turbidity and mean daily discharge were weakly correlated (Spearman Correlation, r_s = 0.42 to 0.37) with these microbiological indicators. Although turbidity is generally low, filtration plus disinfection would be required before drinking water use. Also, fecal coliform and *E.coli* measurements appeared to be visually increasing over the sample period.

Figure 12: Fecal coliform and turbidity measurements (A) and *E. coli* and turbidity measurements (B) from the Moyie River.



pH: pH measurements varied greatly over the sample period from slightly basic to slightly acidic with a median of 7.4 pH units. Since the Moyie River was has relatively low alkalinity, it can be greatly impacted by acid inputs. pH was negatively correlated with flow (Spearman Correlation, r_s = -0.58), thus, depressed pH measurements coincided with higher flows. Although pH approached or was lower than the lower threshold for the B.C. and the CCME aquatic life and drinking water guidelines (Figure 13A), these occurrences were rare, and it is likely that the values were biased low as they coincide with a period of known laboratory issues with pH measurement. pH values do not seem to have changed over time (Figure 13B).

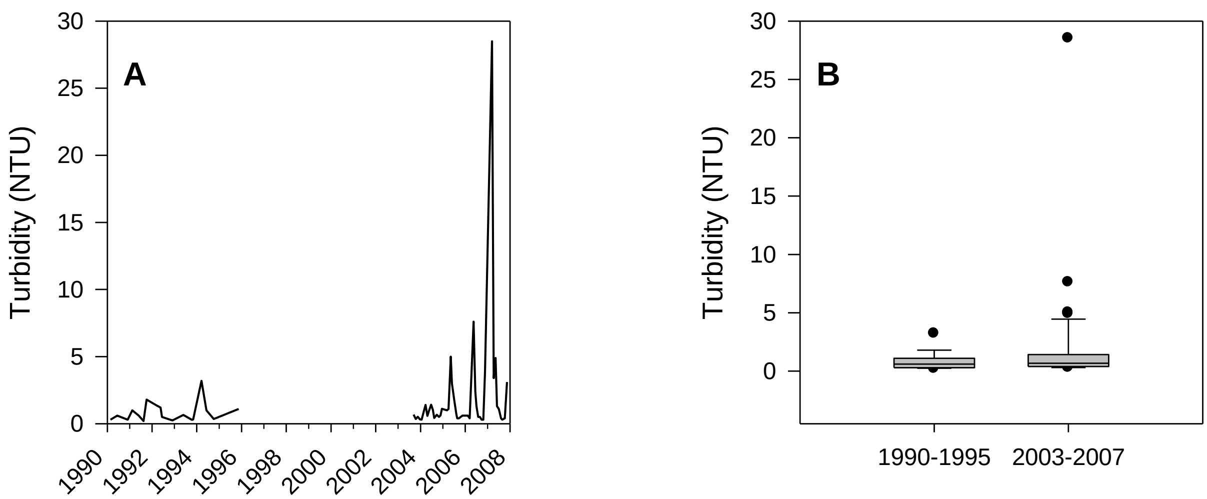
Figure 13: pH measurements over the sample period (A) and box-and-whisker plots comparing pre- and post- site reactivation pH measurements (B).



Note: The dashed line represents the lower threshold for B.C. and CCME aquatic life and drinking water guidelines.

Turbidity: Turbidity is positively correlated with discharge (Spearman Correlation, $r_s = 0.62$), with seasonal maximums coinciding with spring freshet and high flow, and low turbidity coinciding with low flows. Turbidity measurements are particularly important since they are highly correlated with a variety of metals, affecting the prevalence of metal concentrations. Although the time plot of turbidity visually suggests that turbidity has been increasing (Figure 14A), box-and-whisker plots demonstrate that concentrations have remained relatively similar (Figure 14B), and that the increased sampling schedule during the post-site reactivation period has captured greater variation in turbidity concentrations.

Figure 14: Turbidity measurements over time (A) and box-and-whisker plots comparing pre- and post-site reactivation turbidity measurements (B).



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