McMillan Creek Monitoring Project
2006 EPD Data Summary

James Jacklin, B.Sc.
Ministry of Environment
Environmental Protection Division
Environmental Quality Section
Omineca-Peace Region
March, 2007

BRITISH COLUMBIA
The Best Place on Earth
Ministry of Environment

Executive Summary

In the summer of 2006, the Prince George Ministry of Environment initiated a compliance and monitoring project on the McMillan Creek Watershed. For this project, the Environmental Protection Division (EPD), Environmental Quality Section were to undertake a water quality monitoring survey and the Environmental Stewardship Division (ESD), Ecosystems Branch, were to undertake a culvert/fish passage and hydrology compliance project. This report summarizes the results of the EPD program.

Environmental Protection had three tasks to undertake:

1. To obtain baseline water quality information from the various land use sectors in the watershed (no current Water Quality Objective's exist for McMillan Creek),
2. To identify potential contaminant sources,
3. To make recommendations, based on the collected data, on further compliance and remedial projects in the watershed.

Environmental Stewardship had two tasks to undertake:

1. To conduct fish passage assessments at the stream crossings constructed by property owners or by the City of Prince George, and
2. To assess hydrologic conditions at the crossing sites for indications of site instability, lack of capacity, or other issues.

Approach/Results: EPD water monitoring locations were developed from a mapping examination of the McMillan Creek watershed. The McMillan Creek mainstem was segregated based on land use activity and sample sites were created both upstream and downstream from potential pollution sources. The available funding, which was only provided for a preliminary assessment of McMillan Creek, allowed these sites to be sampled four times, including one summer low flow, one summer rain event, one fall rain and during one winter low flow.

Water samples were analyzed for a variety of parameters that were selected based on the respective upstream land use activity for each site. These parameters included total and dissolved metals, nutrients and general chemistry, fecal coliform bacteria and bacterial source tracking. Most parameters have applicable provincial or federal water quality guidelines which were used to help assess the current condition of McMillan Creek.

In addition to the collection of water quality information, benthic invertebrate samples were collected according to the Canadian Aquatic Biomonitoring Network (CABIN) protocol. This bioassessment tool uses living organisms to provide insight on environmental conditions by using the Reference Condition Approach (RCA) (Environment Canada, 2007). This approach uses reference sites, which have minimal human impact, as a baseline for assessing potentially impaired sites (Environment Canada, 2007). The model used in this program, which was analyzed by the Ministry of Environment in Skeena Region, include a BEAST (Benthic Assessment of Sediment) model and a SkeenRivas model, which is based on Australia's modelling program AUSRIVAS.

From the collected water quality information and the benthic invertebrate analysis, McMillan Creek appears to be stressed. The upper portion of the watershed, which is dominated by residential area and hobby farms, as well as the lower sector, which is dominated by commercial and residential areas, appear to have issues with fecal bacteria contamination. Preliminary results suggest possible contamination from ruminant animals, pigs, dogs and humans, especially during low flows. Although there are no recommended bacterial guidelines for the protection of aquatic life (the guidelines are focused on drinking water, irrigation, livestock watering, etc.), there are other potential concerns such as nutrient loading and oxygen depletion that could impact aquatic life.

It was also found that the City storm drain, located upstream from Hoferkamp Road on McMillan Creek (in the lower portion), appears to have a substantial impact on the loading of total suspended solids, bacteria, total phosphorus, nitrate/nitrite, sodium chloride and various potentially toxic metals. Although there may be other contributing sources, such as observed ditch drainage and overland flow, field inspections in October, 2006 clearly showed an impact from the drain's induced TSS and turbidity. If TSS and turbidity levels cannot be reduced at their source, sediment traps or other particulate reducing methods should be used or constructed near the confluence with McMillan Creek to help reduce the direct impact.

Future monitoring efforts on McMillan Creek should include a hydrocarbon and pesticide sediment program and more detailed water quality monitoring focusing on the lower commercial/residential portions and the upper hobby farm portion. Regardless, the data collected during this program suggests that McMillan Creek is currently stressed.

Table of Contents

List of Tables

List of Figures

List of Plates

List of Appendices

1.0 Introduction

In the summer of 2006, the Ministry of Environment (MOE) initiated a compliance project on the McMillan Creek watershed in Prince George. The Environmental Quality Division (EQ) section within the Environmental Protection Division (EPD) undertook a water quality monitoring survey, which was supplemented by a culvert/fish passage and hydrology compliance study performed by the Environmental Stewardship Division (ESD), Ecosystems Branch. This report summarizes the findings of the EQ water quality survey.

2.0 Project Scope and Objectives

This multi-divisional compliance and monitoring project focused on four key objectives:

1. to identify fish passage obstructions (e.g. blocked culverts) and collect basic hydrological data,
2. to determine how various land use sectors in the watershed affect water quality,
3. to identify potential contaminant sources, and
4. to recommend further compliance and remedial projects in the watershed based on the results of the study.

This report provides the results of objectives two, three and four. It is intended to provide direction and guidance for future compliance and enforcement activities in the watershed, as well as recommend best management practices based on the results collected.

3.0 Watershed Overview

3.1 Study Area

McMillan Creek is a small third-order stream located in Prince George, B.C. (Figure 1). The watercourse is 15.25km in length with a watershed area of approximately 55km^2. The stream is located in the north part of the city with a southern aspect. There are various land use activities within this area, including a regional park, commercial businesses, City storm drains, the Aberdeen Glen golf course, residential development, hobby farms and limited forest harvesting.

3.2 Aquatic Environment

McMillan Creek is a direct tributary to the Nechako River and provides habitat for numerous fish species including Chinook salmon (*Oncorhynchus tshawytscha*), bull trout (*Salvelinus confluentus*), northern pikeminnow (*ptychocheilus oregonensis*) and rainbow trout (*Oncorhynchus mykiss*) (Fishwizard, 2006). The bull trout is a blue-listed species in the region, suggesting it is vulnerable to extirpation or extinction. There is a recreational rainbow trout fishery on McMillan Creek; however, angling restrictions apply.

Riparian vegetation varies considerably throughout the watershed. The mouth and bottom one kilometre reach is a densely forested area, followed by two kilometres of 25-75% cover and approximately seven kilometres of 0-50% cover. This large variability is due to numerous reasons including different land use sectors, natural divides separating high gradient forests from low gradient wetlands and a sporadic residential population.

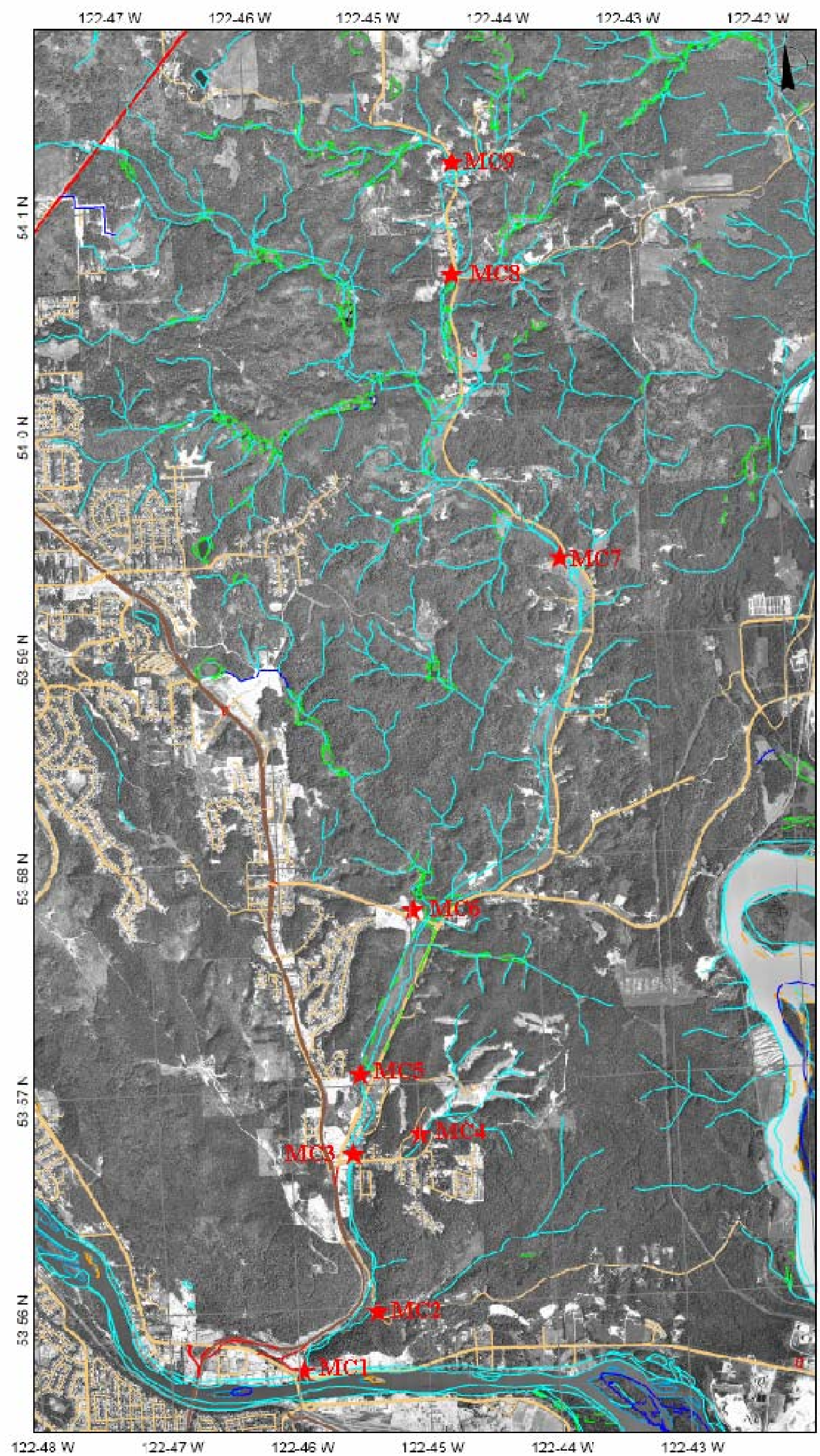


Figure 1. McMillan Creek watershed sample sites. Note, two samples sites were removed due to poor field conditions, sites MC4 and MC9. The map scale is 1:50,000.

4.0 Methodology

4.1 Planning

Meetings were initiated between EPD and ESD in June, 2006 to clarify roles and responsibilities regarding the project, and to discuss monitoring and sampling approaches. Project leads included Bill Arthur, Ecosystem Specialist (ESD), Bob Brade, Ecosystem Biologist (ESD), James Jacklin, Water Technician (EPD) and Dave Sutherland, Environmental Quality Section Head (EPD). Initial sampling plans were discussed, with ESD assuming a lead role in assessing water crossings, hydrology and fisheries assessments and EQ taking the lead on water quality monitoring (it is of note that there are no Water Quality Objectives established on McMillan Creek).

4.2 Water Quality Monitoring Program

Two complementary approaches to assess water quality were used: a baseline monitoring program collecting water samples for analysis, and a biodiversity sampling method using taxonomic richness of benthic macro-invertebrates as indicators of degraded stream quality.

ARCGIS 9 was used to select water monitoring locations by segregating the mainstem of McMillan Creek into major land use activities/corridors. These corridors included a commercial sector, agricultural sector, residential area and areas with combined land uses (Figure 1):

- MC1-Site located at mouth of watershed. All cumulative impacts should be measured at this point.
- MC2-Bacterial data from 2001 (Carmichael and Warren) suggest that this location would have elevated fecal contamination. The site is also downstream from a gas station and City storm drain.
- MC3-Site located downstream from commercial businesses and upstream from of a gas station and City storm drain.
- MC4-Site downstream from Aberdeen Glen golf course.

- MC5-Site upstream from commercial sector.
- MC6-Site upstream from most commercial businesses and downstream from most residential homes and hobby farms.
- MC7-Site divides approximately 50% of the residential homes and hobby farm sector.
- MC8-Site upstream from many hobby farms and downstream from a large subdivision.
- MC9-Site upstream from most residential homes and hobby farms.

A total of nine sites were initially selected (Figure 1) during the office exercise; however, this was reduced to seven sites after field inspections. Site MC4 was eliminated from the program based on non-existent flow conditions and site MC9 was eliminated due to poor access combined with the inability to find a representative site with positive stream flow. Descriptions and pictures of the sample sites are provided in Appendix A. All seven sites were scheduled to be sampled four times based on available budget, once in each of summer low flow, summer rain event, fall rain event and during winter low flow. However, winter low flow samples were not collected due to the stream being completely frozen during the site visit in January 2007. The sampling program ran from July, 2006 to January, 2007.

4.2.1 Physical Data Collection and Analysis

Water samples were analyzed for a variety of parameters that were selected based on the respective upstream land use activity for each site. These parameters included total and dissolved metals, nutrients and general chemistry, fecal bacteria and bacterial source tracking, which uses the Environment Canada bacteroides method (Field et al., 2003) to identify fecal hosts. Most parameters have applicable provincial or federal water quality guidelines. These guidelines represent acceptable levels for a specific resource use including aquatic life (the main focus of this study), potable supply, irrigation, and others. A list of measured parameters, their results and the respective water quality guideline is provided in Appendix B.

Immediately prior to collecting field samples, in-stream conditions were assessed using probes identified in Table 1. Once probe measurement was complete, water samples were collected by inverting uncapped bottles into the stream and then rotating them so that the bottle opening faced upstream into the flow (RISC, 1997). Bottles were not rinsed prior to sample collection, as they are provided by laboratories sterilized and cleansed. Filtering and preserving of metal samples was done by the analyzing laboratory to minimize the possibility for field contamination. The samples were shipped by an overnight courier in coolers with ice packs to Maxxam Analytical Laboratories in Burnaby, B.C. for chemistry, Cantest Laboratories Inc. in Burnaby, B.C. for fecal bacteria and the Pacific Environmental Science Centre in North Vancouver, B.C. for bacterial source tracking analysis. Refer to Appendix C for a summary of analytical techniques.

Table 1. Field probes used during the McMillan Creek sample collection.

Parameter	Probe	Range and Precision
pH	WTW 330i	-2.000 to 19.999pH, ± 0.005
Turbidity	Hach 2100P	0-1000NTU, ± 1% of reading or 0.01NTU, whichever is greater
Dissolved Oxygen	WTW Oxi 330i	0 - 19.99 mg/L, 0 - 90.0 mg/L, 0.0 - 199.9%, 0 - 600% air sat., ± 0.5% of measured value for D.O. and ± 0.1 Temperature
Specific Conductance	WTW 315i	0.0 µS/cm-1999 µS/cm, ± 0.5% of measured value
Temperature	WTW Oxi 330i	± 0.1^{0}C

4.2.2 Quality Assurance and Control

Quality assurance and control (QA/QC) procedures were included in the monitoring program to ensure accuracy and precision of data, field probes, and laboratory analyses. These procedures consisted of project planning, development of data quality objectives, and selection of sampling protocols. QA/QC procedures further included the calibration of field probes using certified standards and the submission of QA samples to the lab.

Approximately 20% of all samples submitted to the lab were QA samples, such as blanks and replicates. De-ionized water was used for field blanks, which was exposed to the environment and handled in the same manner as grab samples (i.e. preservation and cooling), but did not come into contact with ambient water. Field blanks provide a tool to evaluate analytical accuracy at the detection level and can help assess whether contamination occurred through sampling method effects, sampling equipment effects or other sources of contamination. Replicates (samples taken side by side) help assess environmental or natural variability as well as sampling and laboratory analysis procedure consistency or precision. Data quality is determined by comparison of QA sample analysis results to recommended data quality objectives (DQOs) (Table 2). When QA sample results meet these objectives, results of ambient water samples, submitted and analysed at the same time as these QA samples, are accepted as reliable. Otherwise, these data are excluded from analysis and interpretation.

Table 2. Data Quality Objectives set for the McMillan Creek study.

Sample	Acceptable Water Samples
All chemistry Blanks*	< Five times MDL**
All inorganic Replicates***	Relative Percent Difference < 25% from either sample
Bacteria Blanks*	< MDL
Bacteria Replicates	Either sample within 95% Confidence Interval

* Exceptions: 1. Sample > 20 x blank (or blank <10% sample); 2. Sample is below the detection level

** MDL= Method Detection Limit

*** This DQO only applies if concentration > 5 times MDL

4.3 Benthic Monitoring Program

Benthic invertebrate samples were collected on September 6th, 2006 by MOE according to the Canadian Aquatic Biomonitoring Network (CABIN) protocol at site MC1. This bioassessment tool uses living organisms to provide insight on environmental conditions by using the Reference Condition Approach (RCA) (Environment Canada, 2007). This approach uses reference sites, which have minimal human impact, as a baseline for assessing potentially impaired sites (Environment Canada, 2007). The model used in this program, which was analyzed by the Ministry of Environment in Skeena Region, include a BEAST (Benthic Assessment of Sediment) model and a SkeenRivas model, which is based on Australia's modelling program AUSRIVAS. The full results, including detailed analysis, QA/QC procedures, what data were recorded, etc, is summarized in Perrin et al's 2007 report "Bioassessment of streams in north-central British Columbia using the reference condition approach". The results of Perrin et al.'s analysis will be summarized in this report only for site MC1.

5.0 Results

5.1 Data Quality

The bacterial field blank results suggest there was some field or lab contamination of the samples. More specifically, the October 19th, 2006 Enterococci result of 6 CFU/100mL exceeded the Method Detection Limit (MDL) of 1 CFU/100mL. The Fecal Coliform and *Escherichia coli* results from the same day were of good quality. This tends to suggest the contamination occurred somewhere in the field or laboratory, possibly during sampling, filtration or cross contamination between samples. Regardless, as per the DQOs, the October 19th, 2006 Enterococci bacterial data from sites MC3, MC5, MC7 and MC8 were removed from analysis, given the blank exceedance was greater than 10% of the sample value.

The water chemistry field blank and duplicate samples were considered to be of good quality, except for two blank DQO exceedances on October 19th, 2006. Total zinc was detected at 0.7µg/L and dissolved zinc was detected at 0.6µg/L, both exceeding five times their MDL of 0.1µg/L. Zinc contamination is a common problem found in performing laboratory analyses. Both total and dissolved zinc data were removed from analysis for sites MC3 and MC5 on October 19th, 2006, as per the DQOs.

Bacterial source tracking (BST) samples were collected during both the September and October rain events. There were problems during the October event when the mail courier made an error, which caused the samples to arrive at the lab past their respective holding time. Therefore, the October BST results were not analyzed.

All other parameters were considered reliable and were considered suitable for review.

5.2 Water Quality

5.2.1 Bacterial Parameters

Samples were collected for fecal coliform, Enterococci and *E. coli* analyses during this study. As seen in Figure 2, the highest fecal coliform concentration of 4000 CFU/100mL was detected at MC7 during the July 24th low flow. Concentrations decrease downstream from this site until site MC3 when there is another spike in coliform density. Concentrations subsequently declined, likely due to dilution by stream flow.

As seen in the September 21st data, fecal coliform concentrations gradually increase from MC8 to MC6, suggesting fecal input between these sectors. There is a large decline in concentration between MC6 and MC5, followed by a substantial increase at MC2.

E. coli concentrations, presented in Figure 3, show a very close relationship to the fecal coliform results. Although the concentrations differed, the trends were almost identical suggesting that *E. coli* represent a large proportion of the fecal coliforms.

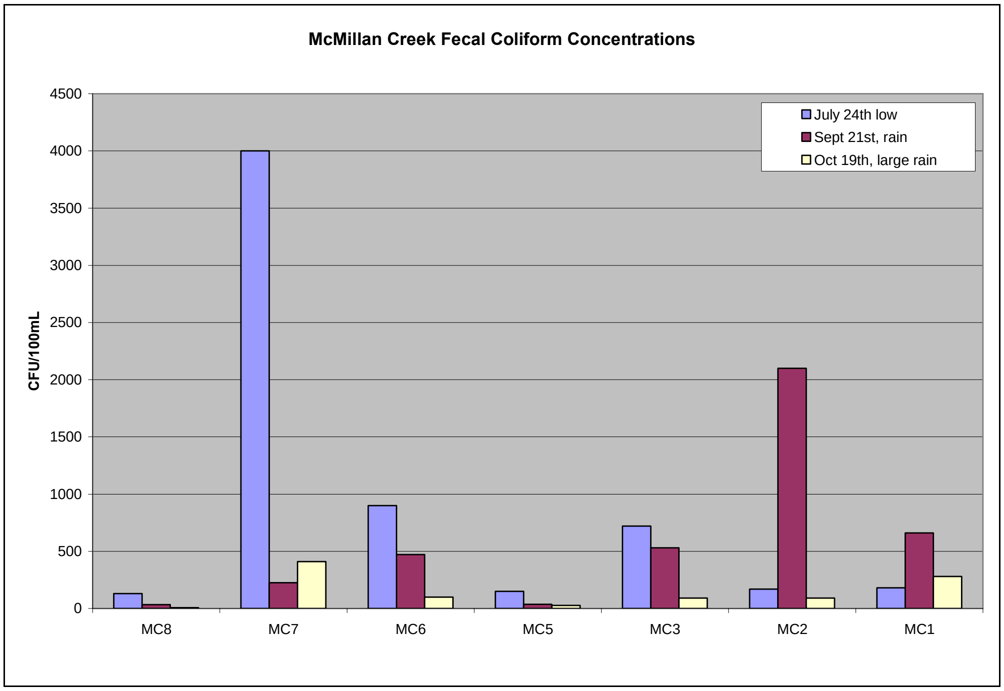


Figure 2. McMillan Creek Fecal Coliform concentrations.

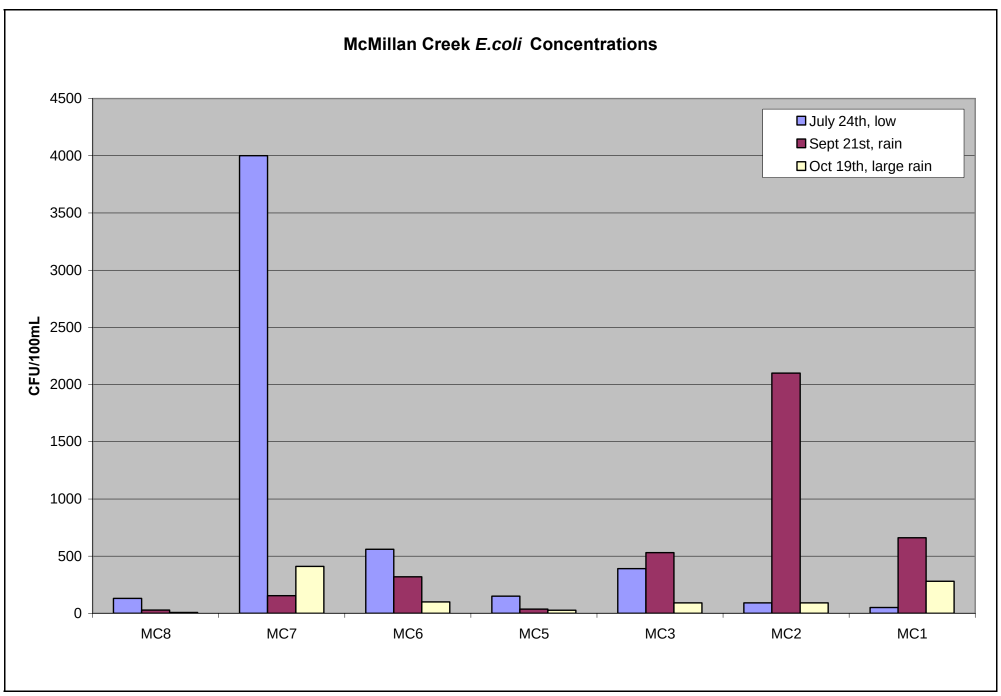


Figure 3. McMillan Creek *E. coli* concentration.

Enterococci results (Figure 4) illustrate a different trend, suggesting the largest inputs originating between sites MC1 and MC3. Large spikes are seen at sites MC2 and MC1 after the September and October rain events, with the October MC1 result of 2300 CFU/100mL being the largest detected. The July low flow samples suggest Enterococci inputs upstream from site MC8, followed by a decline (likely from stream dilution) and a gradual increase from sites MC7 to MC3. The concentrations then decrease from MC3 to MC1.

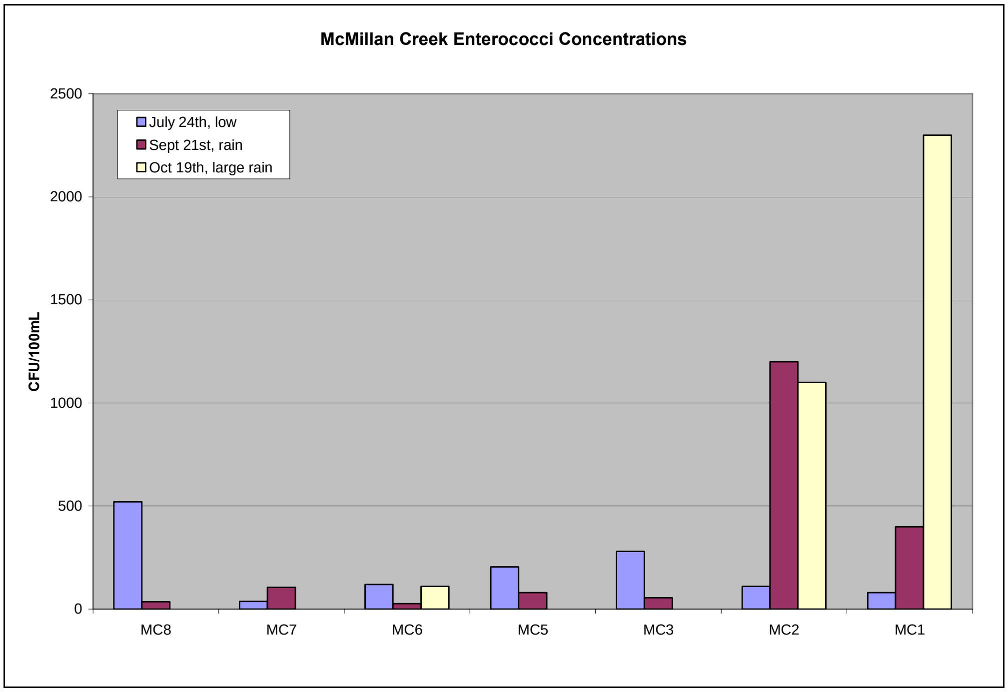


Figure 4. McMillan Creek Enterococci concentrations. It is of note that results from MC3, MC5, MC7 and MC8 for the October sample were removed from analysis due to DQO exceedances.

5.2.2 Bacterial Source Tracking

Bacterial source tracking samples were collected during both the September 21st and October 19th rain event samples. However, as previously mentioned, the October samples exceeded their DQO holding time due to courier error and were not included in this analysis. Although bacterial source tracking is a useful tool to indicate the origin from which fecal pollution is originating, it is limited to simply indicating presence versus absence, rather than providing a more detailed quantitative assessment.

As displayed in Table 3, bacteria originating from ruminant (e.g. cattle, moose, deer) animal and canine were found at site MC1. Although the ruminant animal detection was faint, the laboratory suggests this may be related to the age of the fecal matter, or, because only one genetic marker was detected. Regardless, the results suggest ruminant animal as at least a minor contributing source.

Table 3. BST results from September 21st.

Site	Bacterial Source
MC1	Ruminant Animal*, Dog
MC7	Ruminant Animal, Pig, Dog, Human+

*Faint Detection (only one of two markers detected)

+Potentially Present

The MC7 results indicate that bacteroides from ruminant animal, pig, canine and human were detected in the water column. The presence of human bacteroides was not conclusive; however, the indicator suggests that human fecal pollution was detected.

5.2.3 Chemical Parameters

Chemical parameters were tested by both the field probes listed in Table 1 and by the analysing laboratory. Field probe measurements are listed in Table 4. As displayed in Figure 5, McMillan Creek is slightly alkaline with pH levels ranging from 7.0-8.6. The pH values at site MC2 are unique to the other sites, specifically on October 19th after a precipitation event. On the first two sample dates, pH values were 8.1 and 8.2, decreasing to 7.0 on October 19th. In general, the pH levels appear to decline from MC8 to MC5, after which they increase until MC1.

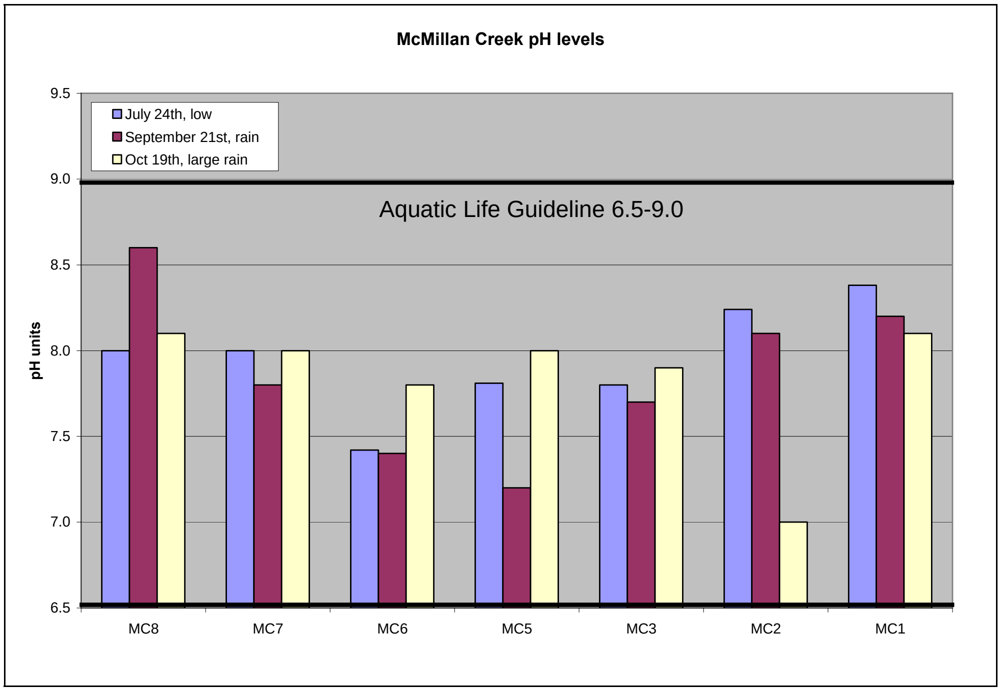


Figure 5. McMillan Creek pH levels.

Table 4. Field probe measurements collected from McMillan Creek.

Date	Site Number	Site Name	UTM	pH	Dissolved Oxygen (mg/L)	Specific Conductance (µS/cm)	Average Turbidity (NTU)*	Average Temperature (ºC)+
07/24/06	MC1	McMillan Creek at Mouth	515372 5975563	8.4	N/A	899	3.6	15.0
09/21/06				8.2	10.1	851	54.0	8.7
10/19/06				8.1	10.7	346	705	6.4
07/24/06	MC2	McMillan Creek at Hoferkamp Road	515951 5976118	8.2	N/A	687	4.11	14.8
09/21/06				8.1	9.9	609	60.6	9.0
10/19/06				7.0	10.8	331	352	5.9
07/24/06	MC3	McMillan Creek at Aberdeen Road	515839 5977357	7.8	N/A	449	4.13	17.1
09/21/06				7.7	7.5	488	4.54	8.1
10/19/06				7.9	9.7	357	5.12	4.7
07/24/06	MC5	McMillan Creek at Northwood Road Crossing	515969 5977902	7.8	N/A	450	5.78	18.3
09/21/06				7.2	7.7	481	10.12	8.2
10/19/06				8.0	8.2	356	5.90	4.8
07/24/06	MC6	McMillan Creek at East Noranda Road	516544 5979352	7.4	N/A	355	2.08	17.9
09/21/06				7.4	5.6	365	3.30	8.0
10/19/06				7.8	8.2	332	1.88	4.0
07/24/06	MC7	McMillan Creek at Hardy Road Crossing	517845 5982333	8.0	N/A	324	2.53	18.8
09/21/06				7.8	8.5	342	3.07	8.5
10/19/06				8.0	10.4	320	3.82	4.2
07/24/06	MC8	McMillan Creek at Goose Country Road Crossing	517033 5984737	8.0	N/A	372	5.23	15.4
09/21/06				8.6	8.2	390	7.29	7.6
10/19/06				8.1	9.6	355	3.41	4.1

*The average turbidity was calculated from two side by side field measurements

+The average temperature was calculated from three of the field probes

N/A= Due to field probe error, data were not available on this date

Dissolved oxygen concentrations appeared to increase in a downstream direction during rain events, with values increasing from about 8 to 9 mg/L at upstream sites to greater than 10 mg/L at site MC1. Of concern was a value of 5.6 mg/L recorded at Site MC6 during the September precipitation event. Aquatic life would be stressed during such events at these concentrations.

Turbidity levels (Figure 6) were generally low with concentrations less than 10 NTU at most sites during most dates; however, there were large spikes at sites MC2 and MC1 during both the September and October rain events. During the September event, levels peaked at site MC2 at 60.6 NTU (although very similar concentrations were at MC1) while concentrations peaked at MC1 during the October event at 705 NTU.

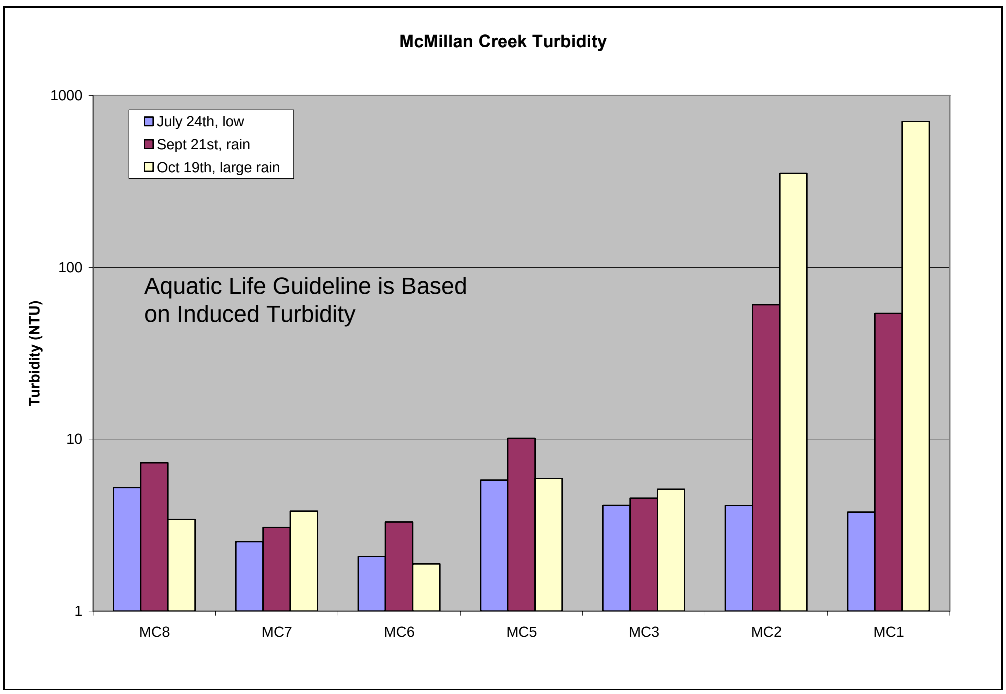


Figure 6. McMillan Creek Turbidity data. The y-axis is log transformed.

Total suspended solid (TSS) results suggest most sites have very low levels. The exceptions are sites MC1 and MC2, specifically during rain events. As seen in Figure 7, concentrations increased to 174 mg/L at MC2 and 324 mg/L at MC1 during the October sample. This suggests a large input of suspended solids between sites MC2 and MC3.

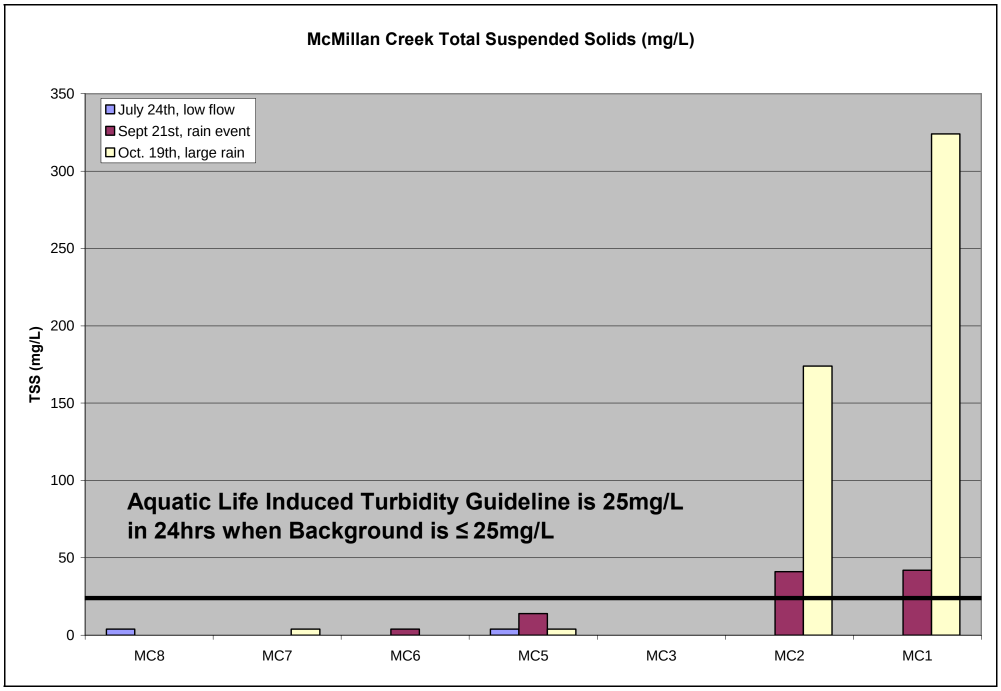


Figure 7. McMillan Creek Total Suspended Solids data.

Specific Conductance levels (Figure 8) typically had very low variability at sites MC3-MC8, while much larger differences were observed at sites MC1 and MC2. During the heavy rain event in October, concentrations appeared to be similar between all sites, while in contrast, during the July low flow concentrations appeared to increase from upstream to downstream.

Sodium and chloride levels, displayed in Figures 9 and 10, show an increasing trend from the top of the watershed to the mouth. The highest concentrations were detected at sites MC1 and MC2 during July and September, with concentrations decreasing during the October rain event. The highest chloride concentration was detected in September at site MC1, with a concentration of 157 mg/L. In contrast, concentrations near the top of the watershed, site MC8, averaged 6.9 mg/L.

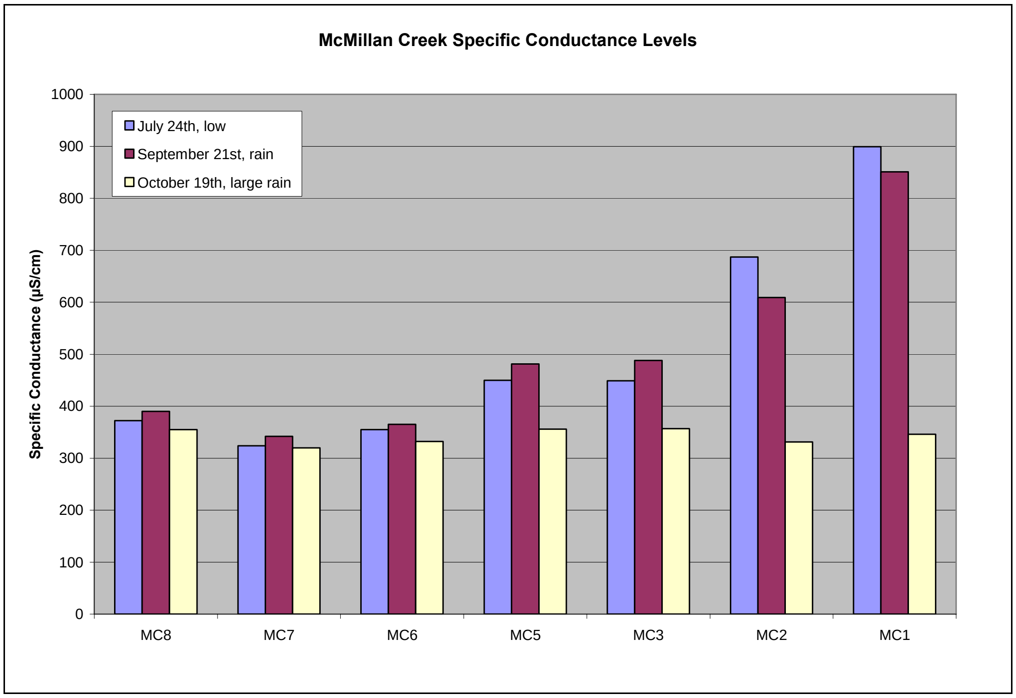


Figure 8. McMillan Creek Specific Conductance Data.

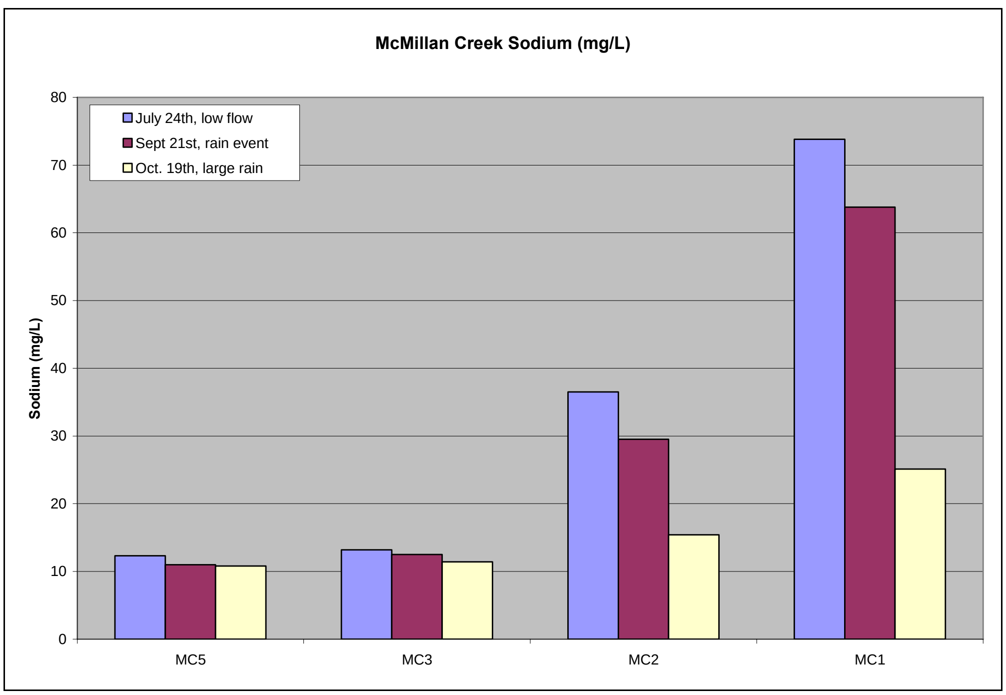


Figure 9. McMillan Creek Total Sodium data.

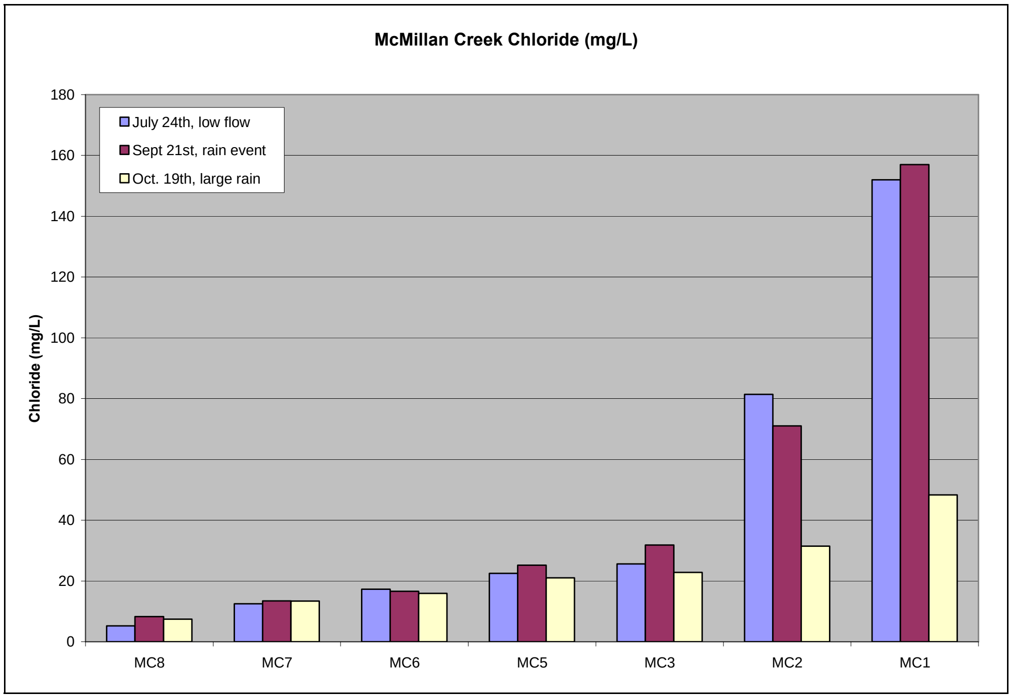


Figure 10. McMillan Creek Dissolved Chloride data.

Nutrient levels were measured in McMillan Creek during the program, with total phosphorus levels being displayed in Figure 11. Although there is no specific water quality guideline for total phosphorus, it is apparent there is a sharp increase in background concentration at site MC2 during the October precipitation event. This suggests a large input upstream from this location; however, it appears to be diluted as levels decrease to somewhat normal conditions at site MC1. The impact from high phosphorus concentrations will be reduced if there are high coincident turbidity levels since light penetration into the water column will become the limiting factor for algal production at such times.

As seen in Figure 12, the nitrate/nitrite concentrations were highly variable between the sites, with elevated levels in the upstream sampling locations that are surrounded by hobby farm and agricultural sectors, followed by a large decrease until a substantial spike at site MC2 and MC1 (downstream from the commercial sector). The highest concentrations were detected during low flows (indicating a persistent/constant, low-level source); however, elevated levels were still found during the high flows in October at sites MC1 and MC2.

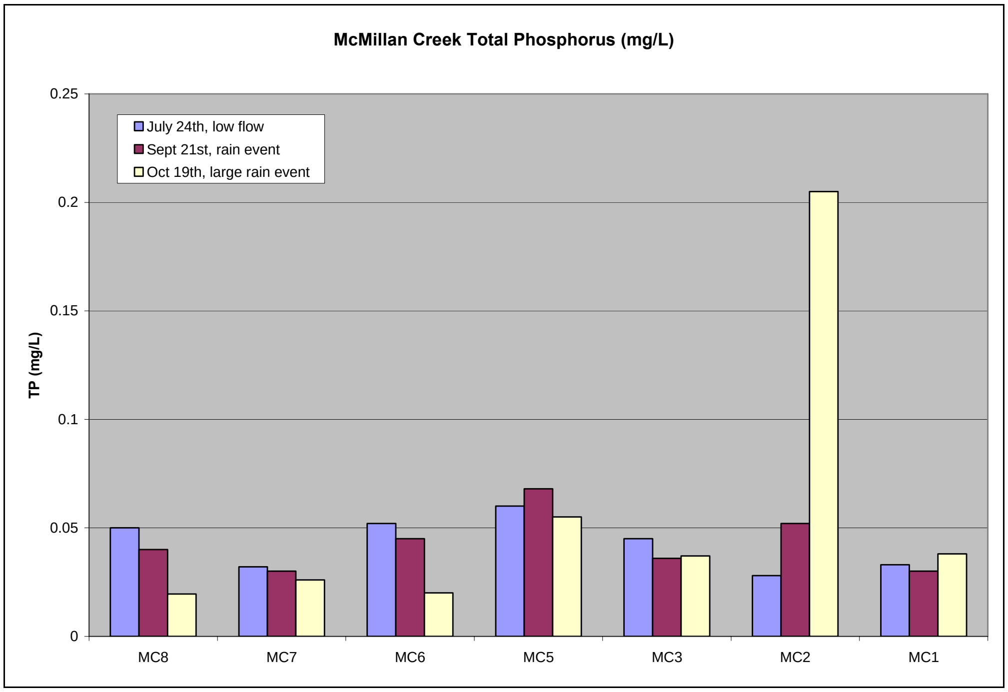


Figure 11. McMillan Creek Total Phosphorus data.

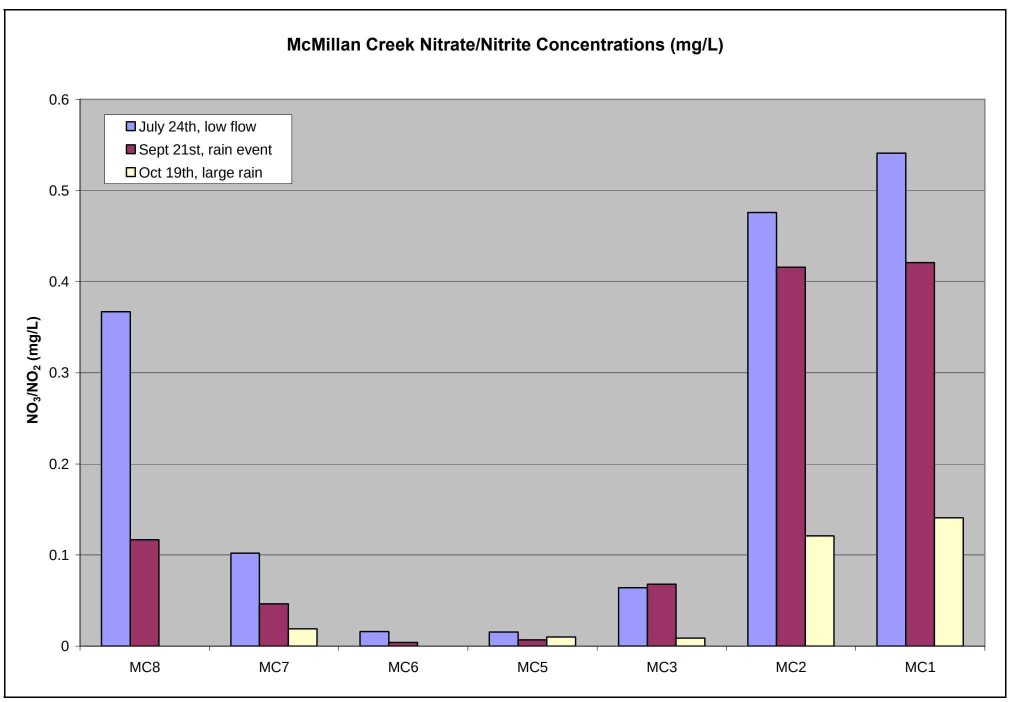


Figure 12. McMillan Creek Nitrate/Nitrite data.

Metals data were collected at the lower sites in the watershed: sites MC1, MC2, MC3 and MC5. Numerous metals had similar trends including total aluminum (Figure 13), total cadmium (Figure 14), total chromium (Figure 15), total cobalt (Figure 16), total copper (Figure 17), total iron (Figure 18), total lead (Figure 19), total manganese (Figure 20), total vanadium (Figure 21) and total zinc (Figure 22). All 10 of these metals had large spikes in concentration during the October rain event at sites MC1 and MC2. These spikes were not detected in the dissolved form (which stayed relatively stable), suggesting the metals were bound to particulates and would likely not be biologically available. This correlates with the large TSS spike during the same time period, originating between sites MC2 and MC3.

Total Manganese had a very high concentration at site MC5 during the July low flow, which differs from any of the other sites or metal tested.

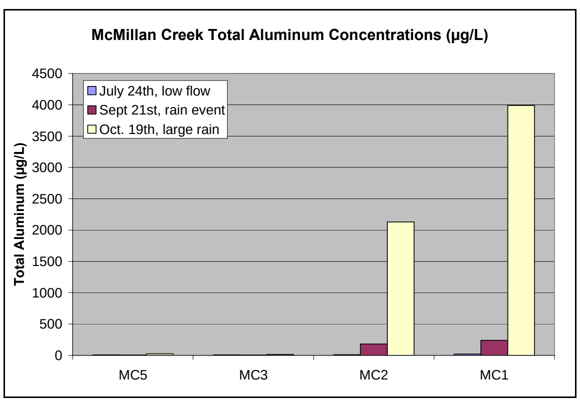


Figure 13. McMillan Creek Total Aluminum.

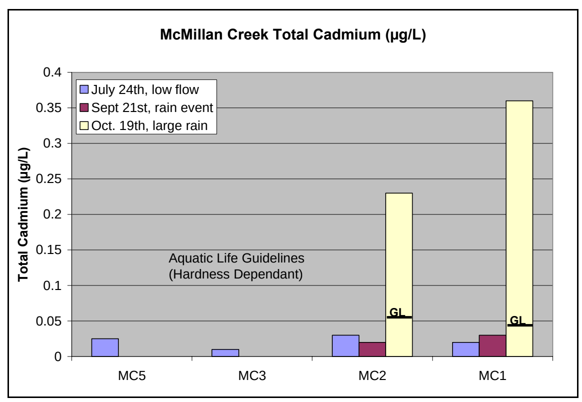


Figure 14. McMillan Creek Total Cadmium. GL=Guideline Level.

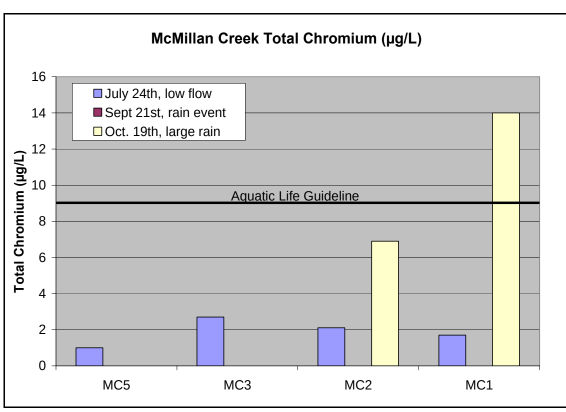


Figure 15. McMillan Creek Total Chromium.

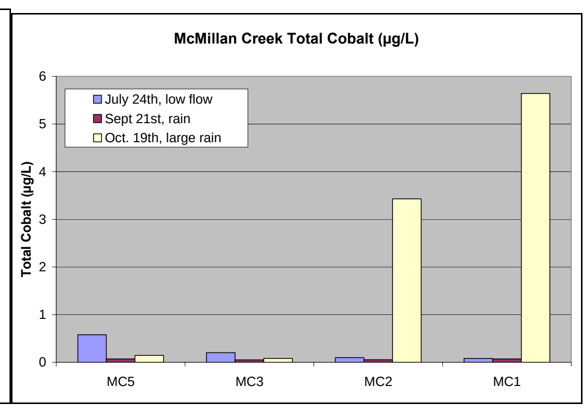
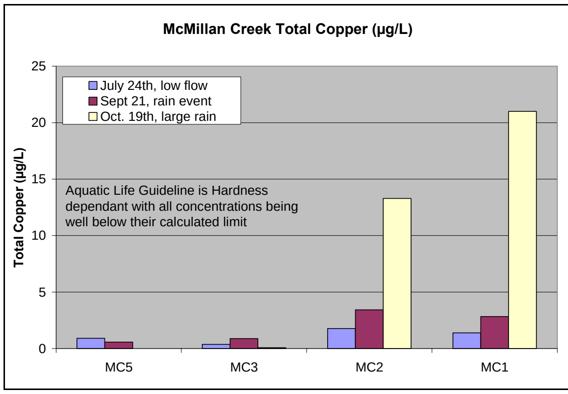


Figure 16. McMillan Creek Total Cobalt.



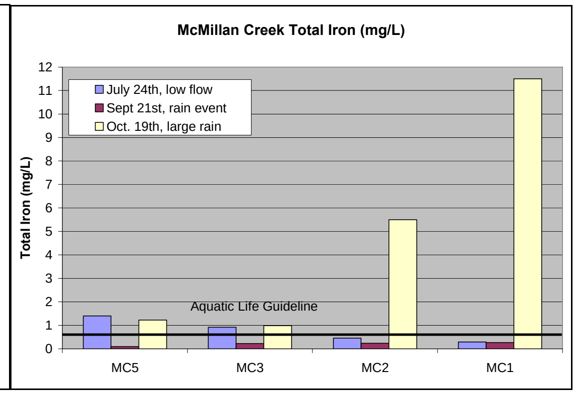
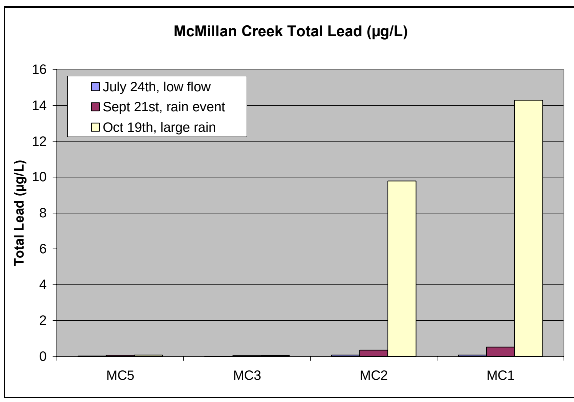


Figure 17. McMillan Creek Total Copper.

Figure 18. McMillan Creek Total Iron.



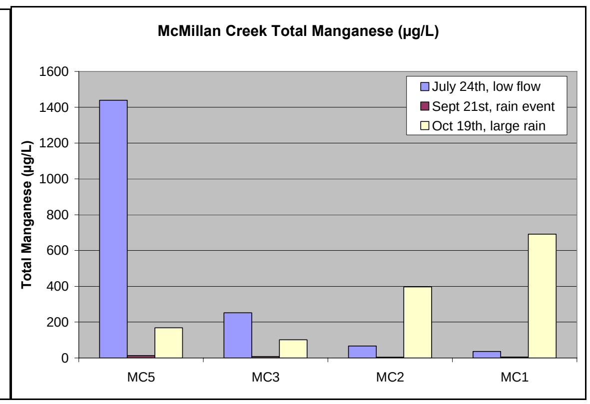
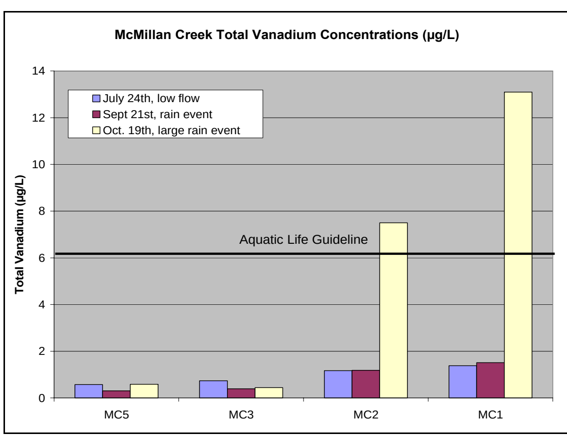


Figure 19. McMillan Creek Total Lead.

Figure 20. McMillan Creek Total Manganese.



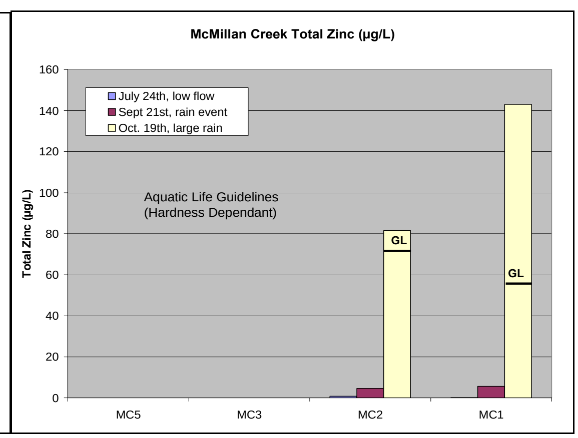


Figure 21. McMillan Creek Total Vanadium.

Figure 22. McMillan Creek Total Zinc. GL=Guideline Level.

5.2.4 Benthic Monitoring

The benthic monitoring analysis results, as found by Perrin et al., 2007, for both the BEAST and SkeenRivas models suggest similar conditions in McMillan Creek (site MC1). The SkeenRivas model result, which is based on an Observed/Expected ratio, was 0.51 (Perrin et al., 2007). The BEAST model ellipse plot result suggested severely stressed conditions. For a detailed summary of results refer to Perrin et al., 2007.

It is of note that of the 227 northern (Skeena, Omineca and Peace) streams tested to date by MOE Skeena Region, model results suggest McMillan Creek at site MC1 to be the second most impaired behind the Kitimat River downstream from Eurocan Pulp and Paper (Perrin et al., 2007).

6.0 Discussion

As displayed in the bacterial results section, some of the highest bacterial concentrations were found at sites MC1 and MC2 after the rain event sampling. The results were usually higher at MC2, suggesting some dilution at the MC1 location. The area dividing sites MC2 and MC3 is not a large area, with most of the coliforms likely originating from the City storm system above Hoferkamp Road; however, a more detailed sampling program is required to confirm this, or, signs should be posted indicating that stream conditions tend to have elevated coliform levels during rainfall events. These results also agree with data collected by the Ministry in 2001 which identified site MC2 as having the highest bacterial concentrations in the watershed (Carmichael and Warren, 2001).

Very high coliform and *E.coli* levels were also detected at site MC7 during the low flow sampling. This sector of the watershed is dominated by hobby farms and wetlands. As seen in the bacterial source tracking data, results suggest inputs by ruminant animals (cattle were observed in the area), pigs, dogs and potentially humans. There are also beaver present in this area; however, the source tracking technology does not yet have genetic coding for this animal. The high concentrations detected during the July low flow suggest a contributing source such as leachate from septic/lagoon systems or fecal contamination from wildlife or livestock. Most of the dog, ruminant and wildlife contributions likely enter the stream by overland flow following precipitation events. The riparian zone is also easily accessed by wildlife and livestock as very few fences were observed along this section of McMillan Creek.

The pH of McMillan Creek appears to drop at site MC6, which is characterized by slow moving, slightly coloured water originating from a wetland complex dammed intermittently by beaver activity. This drop in pH may be due to organic acid formation within the wetland complex. Levels subsequently rise at MC3 which is almost 2km downstream from the wetland complex and are likely influenced more by ground water chemistry than wetland chemistry.

McMillan Creek turbidity and total suspended solid (TSS) levels were found at low concentrations during all dates at all sites, except sites MC2 and MC1 after precipitation events. The increased turbidity and TSS at site MC2 can be attributed to the City storm drain located approximately 500 m upstream from the site. As found during an October 5th field inspection (Plates 1-3), the City storm system substantially increased the TSS and turbidity concentrations of the stream. This induced TSS exceeds the recommended British Columbia aquatic life guideline level (25 mg/L in 24 hours when background concentrations are less than 25 mg/L). This elevated TSS will reduce light penetration in the water and can affect fish and fish habitat (RISC, 1998). The data also suggest the turbidity and TSS levels continue to increase to MC1, which is likely due to overland flow and ditch water.

Plate 1. A view of the City storm drain flowing into McMillan Creek above Hoferkamp Road. Note the highly turbid water.

Plate 2. A downstream view from the confluence between the City storm drain (right) and McMillan Creek (left). Note the clear water in McMillan Creek and the highly turbid water from the City storm drain.

Plate 3. A view of the mixing zone immediately downstream from McMillan Creek and the City storm drain confluence. Note the highly induced turbid water from the City Storm drain (right side of channel) and the clear water from McMillan Creek (left side of channel).

Specific conductance, total sodium and dissolved chloride all showed similar trends increasing in concentration from the top of the watershed to the bottom. Values were particularly high during lower flow conditions, suggesting a large contribution from ground water. This also agrees with Ministry data collected in 2004, which suggests a similar trend (Jacklin, 2004). There is a substantial increase at sites MC2 and MC1, suggesting input from some external sources other than ground water. Natural sources of sodium include the weathering of salt deposits and contact of water with igneous rock. Anthropogenic sources include road salts, sewage and industrial effluents and the use of sodium products in corrosion control and water softening products (Health Canada, 1992).

Nitrate/nitrite data also suggest large contributions from the City storm drain upstream from MC2, with concentrations substantially higher than MC3. Concentrations were low between MC6 and MC3, with slightly elevated levels at MC7 and MC8, which are located near hobby farms on Old Summit Lake Road. This tends to suggest the main inputs are from the residential/hobby farm area upstream from Hardy road and the area upstream from Hoferkamp Road. Nitrate is the primary form of nitrogen used by plants to stimulate growth, with increased concentrations often leading to enhanced periphyton and algal growth (RISC, 1998).

Phosphorus data showed relatively different trends, with no substantial differences between the sites. The one exception was the MC2 October large rain event, when concentrations were substantially higher. Of the large total phosphorus increase, approximately 60% was in the dissolved form, which may be available for biological uptake. Since phosphorus is most often the limited nutrient in aquatic ecosystem, an increased flux might be available for uptake by algae causing proliferations in the stream (RISC, 1998). However, actual growth can be largely impacted as well by available light and this would be reduced when high turbidity levels are present.

The metal results showed elevated levels of Al, Cd, Cr, Co, Cu, Fe, Pb, V, Zn and Mn. The large spikes were initially detected at site MC2, with a further increase at MC1. As previously mentioned, these elevated metals were dominantly in the total form, suggesting they were bound to particulates, also detected in the elevated TSS. This TSS was initially found to be from the City storm drain; however, there also appears to be an increase between sites MC2 and MC1. The source of this second increase is unknown, but it may be due to a combination of overland flow, increased ditch water entering the stream, the re-suspension of settled particles during increased flows, erosion within the creek or other contaminant sources. More detailed monitoring is required to sufficiently identify the contamination sources. Recommended aquatic life guidelines were exceeded by numerous metals, including cadmium, chromium, iron, vanadium and zinc. Although some of these metals may occur naturally in the soils, a description of them and their associated anthropogenic sources are listed below.

Cadmium has highly toxic effects in all of its chemical forms (RISC, 1998). It tends to accumulate in plant cells and can also have extremely toxic effects on trout. Associated metals, including zinc and copper, are known to increase cadmium's toxicity (RISC, 1998). Cadmium also tends to accumulate in the bottom sediments; however, changes in environmental conditions, including a reduction in pH, can allow the metal to be remobilized and transported (CCME, 1999). Anthropogenic sources include effluents from smelting and refining industries, as well as atmospheric fallout (CCME, 1999). Chromium metal, when bioavailable, can bioconcentrate in aquatic plants; however, does not seem to bioaccumulate in fish or invertebrates (CCME, 1999). Chromium ions generally originate from industrial effluents (manufacturing of paints, dyes, explosives, stainless steel, ceramics and paper), fertilizers and pesticides (RISC, 1998).

Elevated iron concentrations may cause fixation of essential elements required by plants and can precipitate on and impair benthic aquatic life (RISC, 1998). Anthropogenic sources include industrial effluents and smelters (RISC, 1998; Manahan, 2000).

Vanadium, especially at high levels, can significantly reduce the growth and feeding response of trout. At substantially high dietary levels, mortality in trout has been observed (Hilton and Bettger, 1988). Vanadium is used in the production of alloys and is a bi-product at power plants from burning petroleum, coal and oil (CCME, 1999).

Zinc, although generally non-toxic to terrestrial organisms, can be acutely and chronically toxic to aquatic organisms, including rainbow trout and other fish (RISC, 1998; Nagpal, 1999). The guideline and associated toxicity is dependant on hardness, salinity, temperature and dissolved oxygen (RISC, 1998; Nagpal, 1999). Typical anthropogenic sources include industrial waste, metal plating, plumbing, fertilizers, pesticides and urban runoff (RISC, 1998; Manahan, 2000).

Manganese also showed similar trends to the other metals, except for the large spike detected at MC5 during low flow conditions. This site is upstream from most of the commercial businesses, but downstream from residential development and a large wetland/beaver complex. Low oxygen concentrations are typical for eutrophic wetlands and can cause manganese to be released from the sediment into the water column (Wetzel 2001). During this very warm, low water period, the oxygen concentrations likely dropped resulting in a chemical shift and the subsequent release of manganese to the water column. Although this peak concentration of 1440 µg/L exceeds the recommended drinking water guideline of 50 µg/L, it is below the aquatic life guideline. The aquatic life guideline for manganese is hardness dependant, which was calculated to be approximately 3000 µg/L (Nagpal, 2001).

The benthic monitoring results, using two different models, suggest McMillan Creek to be severely impaired. This is based on other sites with similar morphology, slope, riparian function, land use activities, etc. This may be due to a variety of reasons, but as previously discussed, elevated metal and nutrient concentrations may be a contributing factor.

7.0 Conclusions and Recommendations

As seen in both the collected water quality information and the benthic invertebrate analysis, McMillan Creek appears to be stressed. The upper sector of the watershed, which is dominated by residential area and hobby farms, as well as the lower sector (downstream from site MC3), which is dominated by commercial and residential areas, appear to have issues with fecal bacteria contamination. As discussed, results suggest possible contamination by ruminant animal, pig, dog and human, especially during low flows (MC7). It is recommended that a more detailed bacterial program be established in this upper sector, which might help to identify these sources, such as leaking septic systems or lagoons. During the sampling program, numerous cattle and horses were observed near the stream (which was unfenced), likely contributing to the contamination. Further sampling in the lower sector, concentrating directly up and downstream from potential sources is also recommended to help identify loading areas. Although there are no recommended bacterial guidelines for the protection of aquatic life (the guidelines are focused on drinking water, irrigation, livestock watering, etc.), there are other potential associated concerns such as nutrient loading and oxygen depletion.

A more detailed assessment of the impact of the City storm drain upstream from site MC2 on McMillan Creek is required. Although this program was very limited in sample number, the results that were collected suggest a large impact on McMillan Creek regarding loading of TSS, bacteria, total phosphorus, nitrate/nitrite, sodium, chloride and various potentially toxic metals (in the total form). Although there may be other contributing sources, such as observed ditch drainage and overland flow, the field inspection in October clearly showed an impact from the drain's induced TSS and turbidity (Plates 1-3). If TSS and turbidity levels cannot be reduced at their source, sediment traps or other particulate reducing methods should be used or constructed near the confluence with McMillan Creek to help reduce the direct impact.

Future monitoring efforts on McMillan Creek should include a hydrocarbon and pesticide sediment program and more detailed water quality monitoring focusing on the sectors between sites MC1 and MC3 and sites upstream from MC7. Unfortunately the budget in this program did not allow for sediment monitoring or an increased water quality sample frequency; however, the data collected did help to identify problem areas and suggests that McMillan Creek is currently stressed.

This study is one part of a broader water quality management program being carried out by the Environmental Quality Section in MOE's Omineca-Peace Region. The overall objectives of this program are to monitor water quality to identify problems, to determine causes, and to work with local governments, landowners and other interested parties to improve or otherwise protect water quality and aquatic life. Information sharing between governments, specifically MOE, Northern Health and various Regional and Municipal governments, is an ongoing practice.

Literature Cited

British Columbia Environmental Laboratory Manual: For the Analysis of Water, Wastewater, Sediment, Biological Materials and Discrete Ambient Air Samples. 2003. Province of British Columbia.

Canadian Council of Ministers of the Environment (CCME). 1999. Canadian water quality guidelines for the protection of aquatic life: Cadmium. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment (CCME). 1999. Canadian water quality guidelines for the protection of aquatic life: Chromium-Hexavalent chromium and trivalent chromium. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment (CCME). 1999. Canadian soil quality guidelines for the protection of environmental and human health: Vanadium (1997) In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Carmichael and Warren. 2001. McMillan Creek Bacterial Survey. Environmental Quality Branch, British Columbia Ministry of Environment.

Environment Canada. 2007. Canadian Aquatic Biomonitoring Network. http://cabin.cciw.ca/Main/cabin_about.asp?Lang=en-ca

Field, K. G, A. E. Bernard and T. J. Brodeur. 2003. Molecular Approaches to Microbio-logical Monitoring: Fecal Source Detection. Environmental Monitoring and Assessment 81: 313-326.

Fishwizard. 2005. Freshwater Fisheries Society of BC. http://www.fishwizard.com/

Hilton, JW; Bettger, WJ. 1988. Dietary vanadium toxicity in juvenile rainbow trout: A preliminary study. Aquatic Toxicology. Vol. 12, no. 1, pp. 63-71.

Jacklin, James. 2004. McMillan Creek Water Monitoring Program, 2004. Province of British Columbia.

Manahan, Stanley E. 2000. Environmental Chemistry. Seventh Edition. New York: Lewis Publishers. 898p.

Nagpal, N.K. 2006. Approved British Columbia Water Quality Guidelines: 2006 Edition. Science and Information Branch. British Columbia Ministry of Environment.

Nagpal, N. K. 2001. British Columbia Water Quality Guidelines: Ambient Water Quality Guidelines for Manganese. Water, Air and Climate Change Branch, British Columbia Ministry of Environment.

Nagpal, N. K. 1999. British Columbia Water Quality Guidelines: Ambient Water Quality Guidelines for Zinc. Water, Air and Climate Change Branch, British Columbia Ministry of Environment.

Perrin, C.J., S. Bennett, S. Linke, A.J. Downie, G. Tamblyn, B. Ells, I. Sharpe, and R. C. Bailey. 2007. Bioassessment of streams in north-central British Columbia using the reference condition approach. Report prepared by Limnotek Research and Development Inc. and B.C. Ministry of Environment for the B.C. Forest Science Program. 121p.

Resource Inventory Standards Committee (RISC). 1997. Ambient Freshwater and Effluent Sampling Manual. Province of British Columbia.

Resource Inventory Standards Committee (RISC). 1998. Guidelines for Interpreting Water Quality Data. Province of British Columbia.

Waters, Tomas F. 1995. Sediment in Streams: Sources, Biological Effects and Control. Maryland: American Fisheries Society. 251p.

Wetzel, Robert G. 2001. Limnology: Lake and River Ecosystems. Third Edition. San Diego: Academic Press. 1006p.

Appendix A

Sample Site Descriptions

Site MC1

Site Description: McMillan Creek at Mouth.

Reason for Sample Location: Site located at mouth of watershed. All cumulative impacts measured at this point.

UTM 10: 515372, 5975563

07/24/06: Low flow sampling, stream very low and clear, garbage observed instream, sample collected in riffle section.
09/21/06: Stream up in volume due to recent rain, turbid appearance
10/19/06: Stream conditions high and turbid, approximately 3.5mm rain in previous 5hours, muddy appearance.

Plate A1. Site MC1. McMillan Creek, downstream view towards the culverts under the Pulpmill Road crossing, September 24th, 2006.

Site MC2

Site Description: McMillan Creek above Hoferkamp Road crossing.

Reason for Sample Location: Bacterial data collected in 2001 suggest this site to have very high concentrations. Site also located downstream from Mohawk and City storm drain.

UTM 10: 515951, 5976118

07/24/06: Low flow sampling, sampled upstream from road crossing, above culvert. Water has good flow, average depth 0.05m, 1.5m wetted width, cobble/gravel substrate, rocks appear very black but no sheens observed.
09/21/06: Slightly turbid, 2.3m wetted width, ditch water draining into creek via culverts downstream from site.
10/19/06: Stream high and turbid, water running into stream downstream from site from road ditch water.

Plate A2. Site MC2. McMillan Creek, upstream from the road crossing, upstream view, September 24th, 2006. Substrate appeared very black however no sheens observed when agitated.

Site MC3

Site Description: McMillan Creek at Aberdeen Road.

Reason for Sample Location: Station located upstream from Mohawk and City storm drain, downstream from Art and Knapps.

UTM 10: 515839, 5977357

07/24/06: Low flow sampling, sampled upstream from road, high amount of periphyton and algae unlike MC2, lower velocity, small rainbow trout observed.
09/21/06: Water appears clear at site, positive flow.
10/19/06: Stream high but still clear, does not appear turbid.

Plate A3. Site MC3. McMillan Creek, upstream from the road crossing, upstream view, September 24th, 2006. Note the green periphyton growth on the rocks.

Site MC4

Site Description: McMillan Creek Tributary from Aberdeen Glen golf course.

Reason for Sample Location: Station downstream from Aberdeen Golf Course runoff.

UTM 10: 516270, 5977357

07/24/06: Channel dry with no flowing water. Water scour marks and sand deposits suggesting flow during freshet and rain events. No water sample collected.

Plate A4. Site MC4. McMillan Creek tributary, upstream view, September 24th, 2006. Note the channel has no flowing water; however, there were some fluvial deposits suggesting flow during spring freshet or other wet periods.

Site MC5

Site Description: McMillan Creek upstream from Northwood Road crossing.

Reason for Sample Location: Station located upstream from Art and Knapps, along with other commercial businesses.

UTM 10: 515969, 5977902

07/24/06: Low flow sampling, cobble substrate with some periphyton (less than MC3), large guard on culvert blocking debris and beaver access, very low velocity however still positive flow, slightly coloured, small rainbow trout observed.
09/21/06: Abundant garbage in stream, slow positive flow, slightly turbid water (more turbid than MC3).
10/19/06: Site high and slightly turbid in appearance, garbage in stream.

Plate A5. Site MC5. McMillan Creek, upstream from road crossing, downstream view, September 24th, 2006. View of the large metal structure blocking large debris from entering the culvert. Note the abundance of vegetation growing instream.

Site MC6

Site Description: McMillan Creek at East Noranda Road crossing.

Reason for Sample Location: Site upstream from most commercial businesses and downstream from most residential homes and hobby farms.

UTM 10: 515969, 5977902

07/24/06: Low flow sampling, sampled upstream from road, debris/beaver guard at site; however, it is blocked by vegetation and tress (from beaver), ponding up area, water sampled downstream from ponding in section with good positive flow.
09/21/06: Water relatively clear, likely from the settling of sediments in the pond upstream from beaver dams.
10/19/06: Rain starting to fall, good flow with clear water.

Plate A6. Site MC6. McMillan Creek, upstream of road crossing, upstream view, September 24th, 2006. View of the small stream draining the large wetland complex.

Site MC7

Site Description: McMillan Creek at Hardy Road crossing.

Reason for Sample Location: Site approximately half way up residential development.

UTM 10: 517845, 5982333

07/24/06: Low flow sampling, good riparian at sample location, cobble/gravel substrate, very little periphyton, in-stream terrestrial vegetation.
09/21/06: Water appears clear, good flow
10/19/06: Site has good flow and clear water

Plate A7. Site MC7. McMillan Creek, upstream from road crossing, upstream view, September 24th, 2006. View of the small stream with abundant riparian vegetation. The site has a cobble substrate.

Site MC8

Site Description: McMillan Creek at Goose Country Road crossing.

Reason for Sample Location: Site located downstream from large subdivision.

UTM 10: 517033, 5984737

07/24/06: Low flow sampling, stream small but still has positive flow, wetted width approximately 0.5m, debris/beaver guard upstream of culvert. Sampled downstream from road due to no suitable upstream location.
09/21/06: Stream low, clear with good flow. Abundant foliage in creek.
10/19/06: Site has good flow with clear water.

Plate A8. Site MC8. McMillan Creek, downstream from road crossing, upstream view, September 24th, 2006. Note the cobble substrate and abundant riparian vegetation.

Site MC9

Site Description: McMillan Creek at unnamed road crossing.

Reason for Sample Location: Site located upstream from most residential houses and farms.

UTM 10: 516965, 5985814

07/24/06: Could not find a suitable sample site with positive flow. Did not collect sample.

Site MC10

Site Description: Blind Blank.

Appendix B

Water Quality Results

McMillan Creek

McMillan Creek		MC1 McMillan Creek at Mouth			MC2 McMillan Creek at Hoferkamp Road			MC3 McMillan Creek at Aberdeen Road			MC5 McMillan Creek at Northwood Road X-ing A				
		07/24/06	09/21/06	10/19/06	07/24/06	09/21/06	10/19/06	07/24/06	09/21/06	10/19/06	07/24/06	07/24/06	07/24/06 Duplicate Average	09/21/06	10/19/06
Parameters	**Units**														
Sample Depth Lower	m	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.1	0.1
Fecal Coliform	CFU/100mL	180	660	280	170	2100	90	720	530	90	130	170	**150**	37	26
E. coli	CFU/100mL	50	660	280	90	2100	90	390	530	90	130	170	**150**	37	26
Enterococci	CFU/100mL	80	400	2300	110	1200	1100	280	55	30	160	250	**205**	80	38
Calculated Parameters															
Total Hardness ($CaCO_3$)	mg/L	320	250	120	290	240	140	240	240	170	220	230	**225**	240	170
Misc. Inorganics															
Dissolved Hardness ($CaCO_3$)	mg/L	320	250	120	290	240	140	240	240	170	220	230	**225**	240	170
Alkalinity (Total as $CaCO_3$)	mg/L	216	154	92.7	223	173	116	203	211	151	209	209	**209**	215	152
Total Organic Carbon (C)	mg/L	11.2	7.9	9.8	11.7	9.0	9.3	17.2	16.2	12.1	18.5	19.6	**19.05**	19.7	12.1
Anions															
Dissolved Sulphate (SO_4)	mg/L	18.4	15.5	8.1	15.5	19.1	6.5	<5 (1)	<0.5	4	<5 (1)	<5 (1)		<0.5	3.5
Chloride (Cl)	mg/L	152	157	48.3	81.4	71.0	31.5	25.6	31.8	22.8	22.5	22.6	**22.55**	25.2	21
Dissolved Metals by ICPMS															
Dissolved Aluminum (Al)	µg/L	1.8	14.2	14.4	1.8	9.1	12.5	3.1	2.0	2.5	3.8	3.5	**3.65**	1.6	3
Dissolved Antimony (Sb)	µg/L	0.066	0.222	0.332	0.061	0.190	0.216	0.044	0.043	0.04	0.052	0.055	**0.0535**	0.048	0.037
Dissolved Arsenic (As)	µg/L	1.1	0.4	0.5	1.2	0.5	0.5	1.7	1.1	0.7	2.2	2.3	**2.25**	1.5	0.7
Dissolved Barium (Ba)	µg/L	123	126	58.2	93.5	93.2	57	77.3	69.0	63.2	93.7	87.8	**90.75**	70.3	65.6
Dissolved Beryllium (Be)	µg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02
Dissolved Bismuth (Bi)	µg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02
Dissolved Cadmium (Cd)	µg/L	0.02	0.03	0.04	0.02	0.02	0.03	0.01	<0.01	<0.01	0.02	0.02	**0.02**	<0.01	<0.01
Dissolved Chromium (Cr)	µg/L	1.2	<1	1.6	0.9	<1	0.7	0.9	<1	<0.2	0.7	0.7	**0.7**	<1	<0.2
Dissolved Cobalt (Co)	µg/L	0.042	<0.005	0.088	0.072	0.006	0.123	0.186	0.033	0.047	0.477	0.447	**0.462**	0.079	0.084
Dissolved Copper (Cu)	µg/L	1.22	2.51	1.77	1.59	2.81	1.79	0.32	0.85	<0.05	0.65	0.67	**0.66**	0.47	<0.05
Dissolved Lead (Pb)	µg/L	<0.01	0.21	0.06	0.01	0.16	0.08	<0.01	0.04	0.01	0.01	<0.01	**0.01**	0.04	0.01
Dissolved Lithium (Li)	µg/L	2.17	2.82	2.58	1.79	2.48	1.73	1.15	0.94	0.86	1.18	1.12	**1.15**	0.88	0.94
Dissolved Manganese (Mn)	µg/L	16.5	0.451	17.9	43.7	0.377	33.2	220	1.64	40.6	1210	1130	**1170**	1.98	96.1
Dissolved Molybdenum (Mo)	µg/L	3.16	2.61	1.75	3.2	2.64	1.37	3.18	2.43	1.11	3.4	3.37	**3.385**	2.65	1.1
Dissolved Nickel (Ni)	µg/L	1.29	1.23	1.45	1.54	1.49	1.3	1.95	2.07	0.69	1.81	1.7	**1.755**	1.78	0.56
Dissolved Selenium (Se)	µg/L	0.8	0.4	<0.2	1	0.5	0.3	<0.2	<0.2	0.2	0.3	0.3	**0.3**	<0.2	<0.2
Dissolved Silver (Ag)	µg/L	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	**0.02**	<0.02	<0.02
Dissolved Strontium (Sr)	µg/L	374	374	158	329	326	166	272	323	191	266	248	**257**	319	189
Dissolved Thallium (Tl)	µg/L	0.002	0.003	0.003	0.002	<0.002	0.003	<0.002	<0.002	<0.002	0.002	<0.002	**0.002**	<0.002	<0.002
Dissolved Tin (Sn)	µg/L	0.01	0.01	0.01	<0.01	0.01	0.01	0.03	<0.01	<0.01	<0.01	<0.01		<0.01	0.01
Dissolved Uranium (U)	µg/L	1.24	1.13	0.307	1.01	1.01	0.316	0.458	0.456	0.237	0.461	0.457	**0.459**	0.487	0.235
Dissolved Vanadium (V)	µg/L	1.51	1.55	0.57	1.15	1.11	0.45	0.47	0.31	0.34	0.43	0.4	**0.415**	0.30	0.43
Dissolved Zinc (Zn)	µg/L	<0.1	2.6	2.7	<0.1	2.0	1.8	<0.1	<0.5	<0.1	<0.1	<0.1		<0.5	<0.1
Leachable Metals															
Total Aluminum (Al)	µg/L	19.4	240	3990	9.9	181	2130	5.8	4.2	15	7.5	8.8	**8.15**	3.2	26.5
Total Antimony (Sb)	µg/L	0.068	0.232	0.511	0.056	0.193	0.344	0.051	0.051	0.037	0.049	0.055	**0.052**	0.050	0.037
Total Arsenic (As)	µg/L	1.1	0.8	2.4	1.2	0.8	1.6	1.8	1.6	0.9	2.6	2.6	**2.6**	1.9	1.1
Total Barium (Ba)	µg/L	139	134	199	108	102	133	85.1	73.9	66.2	114	115	**114.5**	71.5	70.4
Total Beryllium (Be)	µg/L	<0.02	<0.02	0.19	<0.02	<0.02	0.15	0.05	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02
Total Bismuth (Bi)	µg/L	<0.02	<0.02	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02
Total Cadmium (Cd)	µg/L	0.02	0.03	0.36	0.03	0.02	0.23	0.01	<0.01	<0.01	0.02	0.03	**0.025**	<0.01	<0.01
Total Chromium (Cr)	µg/L	1.7	<1	14	2.1	<1	6.9	2.7	<1	<0.2	1.1	0.9	**1**	<2	<0.2
Total Cobalt (Co)	µg/L	0.082	0.072	5.64	0.098	0.053	3.43	0.202	0.051	0.082	0.572	0.584	**0.578**	0.070	0.145
Total Copper (Cu)	µg/L	1.39	2.84	21	1.77	3.43	13.3	0.37	0.88	0.07	0.95	0.88	**0.915**	0.57	<0.05
Total Lead (Pb)	µg/L	0.08	0.52	14.3	0.08	0.35	9.79	0.01	0.04	0.05	0.02	0.02	**0.02**	0.06	0.07
Total Lithium (Li)	µg/L	2.16	2.83	5.54	1.87	2.61	3.46	1.06	0.98	0.9	1.17	1.04	**1.105**	0.89	1.02
Total Manganese (Mn)	µg/L	36.3	4.83	692	66.3	4.68	397	252	7.66	102	1360	1520	**1440**	13.3	168
Total Molybdenum (Mo)	µg/L	3.02	2.39	1.92	3.03	2.60	1.48	3.14	2.48	1.1	3.43	3.47	**3.45**	2.65	1.08
Total Nickel (Ni)	µg/L	1.57	1.32	22	1.82	1.41	11.5	2.02	1.90	0.82	2.13	1.96	**2.045**	1.57	0.8
Total Selenium (Se)	µg/L	0.8	0.9	<0.2	0.9	0.8	0.2	0.4	0.3	0.2	0.3	0.3	**0.3**	0.3	<0.2
Total Silver (Ag)	µg/L	0.04	<0.02	0.05	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	0.05	**0.05**	<0.02	<0.02
Total Strontium (Sr)	µg/L	413	399	188	361	352	188	297	365	195	304	303	**303.5**	343	194
Total Thallium (Tl)	µg/L	<0.002	0.008	0.042	<0.002	0.011	0.023	<0.002	<0.002	<0.002	<0.002	<0.002		<0.002	<0.002
Total Tin (Sn)	µg/L	0.01	0.03	0.07	0.01	0.01	0.03	0.02	<0.01	<0.01	<0.01	<0.01		0.01	0.01
Total Uranium (U)	µg/L	1.19	1.09	0.472	1	0.969	0.423	0.469	0.422	0.235	0.504	0.523	**0.5135**	0.456	0.246
Total Vanadium (V)	µg/L	1.38	1.51	13.1	1.17	1.18	7.5	0.73	0.39	0.44	0.57	0.58	**0.575**	0.30	0.58
Total Zinc (Zn)	µg/L	0.1	5.6	143	0.8	4.6	81.6	<0.1	<1	0.3	<0.1	<0.5 (1)		<1	0.5
MISCELLANEOUS															
True Colour	Col. Unit	30	30	10	30	20	30	70	40	40	70	60	**65**	40	40
Nutrients															
Total Kjeldahl Nitrogen (Calc)	mg/L	0.42	0.26	0.25	0.48	0.26	0.33	0.76	0.67	0.46	0.91	0.89	**0.9**	0.70	0.45
Dissolved Phosphorus (P)	mg/L	0.018	0.013	0.041	0.02	0.013	0.121	0.022	0.029	0.036	0.029	0.028	**0.0285**	0.028	0.042
Nitrate plus Nitrite (N)	mg/L	0.541	0.421	0.141	0.476	0.416	0.121	0.064	0.068	0.009	0.017	0.014	**0.0155**	0.007	0.01
Total Nitrogen (N)	mg/L	0.96	0.68	0.39	0.96	0.67	0.45	0.83	0.74	0.47	0.92	0.91	**0.915**	0.71	0.46
Total Phosphorus (P)	mg/L	0.033	0.030	0.038	0.028	0.052	0.205	0.045	0.036	0.037	0.054	0.066	**0.06**	0.068	0.055
Physical Properties															
Conductivity	µS/cm	898	803	349	680	587	329	446	469	355	447	447	**447**	460	350
pH	pH Units	8.3			8.3			8.2			8.1	8.1	**8.1**		
Physical Properties															
Total Suspended Solids	mg/L	<4	42	324	<4	41	174	<4	<4	<4	<4	4	**4**	14	4
Total Dissolved Solids	mg/L	574			484			330			304	311	**307.5**		
Turbidity	NTU	3.2	21.8	344	2.9	28.3	215	4	3.3	4.4	5.6	5.2	**5.4**	6.0	4.9
Dissolved Metals by ICP															
Dissolved Calcium (Ca)	mg/L	79.7	63.3	30.7	72.4	61.0	36	61.2	63.1	43.1	58.5	60.7	**59.6**	63.1	42.8
Dissolved Iron (Fe)	mg/L	0.043	0.011	0.041	0.1	0.016	0.08	0.468	0.051	0.315	0.618	0.635	**0.6265**	0.017	0.391
Dissolved Magnesium (Mg)	mg/L	29.4	21.7	10.2	27.1	22.0	12.4	20.1	20.7	15.6	19	19.8	**19.4**	20.5	15.4
Dissolved Potassium (K)	mg/L	3			3			2			3	2	**2.5**		
Dissolved Sodium (Na)	mg/L	73.7			35.8			13.2			11.7	12.1	**11.9**		
Total Metals by ICP															
Total Calcium (Ca)	mg/L	82.5	60.2	35.2	76.2	57.9	39.6	62.3	60.1	45	63.2	63.5	**63.35**	60.8	44.4
Total Iron (Fe)	mg/L	0.289	0.263	11.5	0.45	0.240	5.5	0.92	0.221	0.983	1.39	1.41	**1.4**	0.091	1.22
Total Magnesium (Mg)	mg/L	29.6	20.6	13.6	27.9	20.8	14.4	20	19.7	16.1	20.2	20.2	**20.2**	19.8	15.9
Total Potassium (K)	mg/L	3	3	3	3	3	3	2	3	4	2	2	**2**	3	3
Total Sodium (Na)	mg/L	73.8	63.8	25.1	36.5	29.5	15.4	13.2	12.5	11.4	12.3	12.3	**12.3**	11.0	10.8
Total Bromide (Ba)	mg/L		<0.1	<0.1		<0.1	<0.1		<0.1	<0.1				<0.1	<0.1

McMillan Creek		MC6 McMillan Creek at East Noranda Road			MC7 McMillan Creek at Hardy Road X-ing					MC8 McMillan Creek at Goose Country Road					MC10 BLIND BLANK		
		07/24/06	09/21/06	10/19/06	07/24/06	09/21/06	09/21/06	09/21/06 Duplicate Average	10/19/06	07/24/06	09/21/06	10/19/06	10/19/06	10/19/06 Duplicate Average	07/24/06	09/21/06	10/19/06
Parameters	**Units**																
Sample Depth Lower	m	0.1	0.1	0.1	0.1	0.1	0.1		0.1	0.1	0.1	0.1	0.1				
Fecal Coliform	CFU/100mL	900	470	100	4000	160	290	**225**	410	130	34	7	5	6	< 1		<1
E. coli	CFU/100mL	560	320	100	4000	160	150	**155**	410	130	27	7	5	6	< 1		<1
Enterococci	CFU/100mL	120	26	110	37	110	100	**105**	9	520	36	<1	5	3	< 1		6
Calculated Parameters																	
Total Hardness ($CaCO_3$)	mg/L														<0.5		<0.5
Misc. Inorganics																	
Dissolved Hardness ($CaCO_3$)	mg/L														<0.5		<0.5
Alkalinity (Total as $CaCO_3$)	mg/L	165	160	145	152	152	152	**152**	148	191	188	171	172	171.5	0.8		<0.5
Total Organic Carbon (C)	mg/L	14	13.3	11	13.7	13.4	13.4	**13.4**	10.6	10.9	8.4	8.4	8.3	8.35	<0.5		0.8
Anions																	
Dissolved Sulphate (SO_4)	mg/L	<0.5	5	5.5	<0.5	6.6	6.5	**6.55**	4.9	<0.5	7.8	10.1	9.7	9.9	<0.5		<0.5
Chloride (Cl)	mg/L	17.3	16.6	15.9	12.5	13.3	13.6	**13.45**	13.4	5.2	8.3	7.5	7.4	7.45	<0.5		<0.5
Dissolved Metals by ICPMS																	
Dissolved Aluminum (Al)	µg/L														<0.3		<0.3
Dissolved Antimony (Sb)	µg/L														<0.005		<0.005
Dissolved Arsenic (As)	µg/L														<0.1		<0.1
Dissolved Barium (Ba)	µg/L														0.03		<0.02
Dissolved Beryllium (Be)	µg/L														<0.02		<0.02
Dissolved Bismuth (Bi)	µg/L														<0.02		<0.02
Dissolved Cadmium (Cd)	µg/L														<0.01		<0.01
Dissolved Chromium (Cr)	µg/L														<0.2		<0.2
Dissolved Cobalt (Co)	µg/L														<0.005		<0.005
Dissolved Copper (Cu)	µg/L														0.22		0.2
Dissolved Lead (Pb)	µg/L														<0.01		<0.01
Dissolved Lithium (Li)	µg/L														<0.05		<0.05
Dissolved Manganese (Mn)	µg/L														<0.008		<0.008
Dissolved Molybdenum (Mo)	µg/L														<0.05		<0.05
Dissolved Nickel (Ni)	µg/L														<0.05		<0.05
Dissolved Selenium (Se)	µg/L														<0.2		<0.2
Dissolved Silver (Ag)	µg/L														<0.02		<0.02
Dissolved Strontium (Sr)	µg/L														<0.005		0.009
Dissolved Thallium (Tl)	µg/L														<0.002		<0.002
Dissolved Tin (Sn)	µg/L														<0.01		0.01
Dissolved Uranium (U)	µg/L														0.002		<0.002
Dissolved Vanadium (V)	µg/L														<0.06		<0.06
Dissolved Zinc (Zn)	µg/L														<0.1		0.6
Leachable Metals																	
Total Aluminum (Al)	µg/L														<0.3		0.4
Total Antimony (Sb)	µg/L														<0.005		<0.005
Total Arsenic (As)	µg/L														<0.1		<0.1
Total Barium (Ba)	µg/L														0.04		<0.02
Total Beryllium (Be)	µg/L														<0.02		<0.02
Total Bismuth (Bi)	µg/L														<0.02		<0.02
Total Cadmium (Cd)	µg/L														<0.01		<0.01
Total Chromium (Cr)	µg/L														<0.2		<0.2
Total Cobalt (Co)	µg/L														<0.005		<0.005
Total Copper (Cu)	µg/L														0.23		0.2
Total Lead (Pb)	µg/L														<0.01		<0.01
Total Lithium (Li)	µg/L														<0.05		<0.05
Total Manganese (Mn)	µg/L														0.013		<0.008
Total Molybdenum (Mo)	µg/L														<0.05		<0.05
Total Nickel (Ni)	µg/L														<0.05		<0.05
Total Selenium (Se)	µg/L														<0.2		<0.2
Total Silver (Ag)	µg/L														<0.02		<0.02
Total Strontium (Sr)	µg/L														<0.005		0.01
Total Thallium (Tl)	µg/L														<0.002		<0.002
Total Tin (Sn)	µg/L														<0.01		0.02
Total Uranium (U)	µg/L														<0.002		<0.002
Total Vanadium (V)	µg/L														<0.06		<0.06
Total Zinc (Zn)	µg/L														0.1		0.7
MISCELLANEOUS																	
True Colour	Col. Unit	50	40	30	40	40	40	**40**	30	40	30	20	20	20	<5		<5
Nutrients																	
Total Kjeldahl Nitrogen (Calc)	mg/L	0.69	0.52	0.41	0.64	0.53	0.52	**0.525**	0.42	0.5	0.3	0.31	0.31	0.31	<0.02		<0.02
Dissolved Phosphorus (P)	mg/L	0.03	0.031	0.02	0.026	0.025	0.026	**0.0255**	0.02	0.031	0.029	0.019	0.018	0.0185	0.002		<0.002
Nitrate plus Nitrite (N)	mg/L	0.016	0.004	<0.002	0.102	0.043	0.05	**0.0465**	0.019	0.367	0.117	<0.002	<0.002	<0.002	<0.002		0.007
Total Nitrogen (N)	mg/L	0.71	0.53	0.41	0.74	0.57	0.57	**0.57**	0.44	0.87	0.42	0.31	0.31	0.31	<0.02		<0.02
Total Phosphorus (P)	mg/L	0.052	0.045	0.02	0.032	0.031	0.029	**0.03**	0.026	0.05	0.04	0.02	0.019	0.0195	<0.002		<0.002
Physical Properties																	
Conductivity	µS/cm	354	351	328	323	336	337	**336.5**	322	370	383	355	354	354.5	1		1
pH	pH Units	8			8.2					8.2					6.2		
Physical Properties																	
Total Suspended Solids	mg/L	<4	4	<4	<4	<4	<4	**<4**	4	4	<4	<4	<4	<4	<4		<4
Total Dissolved Solids	mg/L	256			218					252					<10		
Turbidity	NTU	2.3	2.3	2.5	2	2.3	2.3	**2.3**	2.5	4.4	5.5	2.5	2.4	2.45	0.4		<0.1
Dissolved Metals by ICP																	
Dissolved Calcium (Ca)	mg/L														<0.05		<0.05
Dissolved Iron (Fe)	mg/L														<0.005		<0.005
Dissolved Magnesium (Mg)	mg/L														<0.05		<0.05
Dissolved Potassium (K)	mg/L														<1		
Dissolved Sodium (Na)	mg/L														<0.05		
Total Metals by ICP																	
Total Calcium (Ca)	mg/L														<0.05		<0.05
Total Iron (Fe)	mg/L														<0.005		<0.005
Total Magnesium (Mg)	mg/L														<0.05		<0.05
Total Potassium (K)	mg/L														<1		<1
Total Sodium (Na)	mg/L														<0.05		<0.05
Total Bromide (Ba)	mg/L		<0.1	<0.1		<0.1	<0.1	**<0.1**	<0.1		<0.1	<0.1	<0.1	<0.1			<0.1

(yellow)	QA Exceedance
(red)	Removed from dataset due to QA exceedance

Table B2: Approved provincial water quality guidelines for general water chemistry and bacteria (Nagpal, 2006).

Parameter	Water User	Guideline
Fecal Coliforms	Potable[1] Potable[2] Recreation[3]	0 CFU/100 mL $\leq$ 10/100mL 90th percentile $\leq$ 200/100mL geometric mean
Enterococci	Potable[1] Potable[2] Recreation[3]	0 CFU/100 mL $\leq$ 3/100mL 90th percentile $\leq$ 20/100mL geometric mean
Escherichia coli	Potable[1] Potable[2] Recreation[3]	0 CFU/100 mL $\leq$ 10/100mL 90th percentile $\leq$ 77/100mL geometric mean
Alkalinity	Aquatic Life	<10 mg/L $CaCO_3$ highly sensitive to acid inputs 10-20 is moderate > 20 low sensitivity
Carbon – Total Organic	Potable Supply	4 mg/L when chlorination
Chloride – Dissolved	Potable	250 mg/L – aesthetics
Colour (True)	Potable	15 without colour removal 75 with colour removal
Conductivity, Specific	Potable	700 µS/cm
Cyanide (Weak Acid Dissociable)	Aquatic Life	10 µg/L maximum
Fluoride	Drinking Aquatic Life	1.5 mg/L Maximum 0.2 mg/L hardness < 50 mg/L $CaCO_3$ 0.3 mg/L hardness ≥ 50 mg/L $CaCO_3$
Hardness – Total Dissolved	Potable	> 500 mg/L unacceptable
Nitrate	Potable Aquatic Life	10 mg/L maximum 200 mg/L maximum
Nitrite	Potable Aquatic Life	1 mg/L maximum Value based on chloride – refer to guidelines
Phosphorus		None Proposed
Sulphate-Dissolved	Potable Aquatic Life	500 mg/L, maximum 100 mg/L, maximum
Turbidity	Potable	1 NTU – health, 5 NTU aesthetic

[1]Water quality guideline for a drinking water source with no treatment.
[2]Water quality guideline for a drinking water source with disinfection only.
[3]Recreation-primary contact.

Table B3. Approved provincial water quality guidelines for metals (Nagpal, 2006).

Parameter	Water Use	Guideline
Aluminum	Potable Aquatic Life	0.2 mg/L Dissolved 0.1 mg/L @ pH ≥ 6.5
Antimony	Potable Aquatic Life	14 µg/L (total) 20 µg/L – Ontario guideline
Arsenic	Potable Aquatic Life	10 µg/L 50 µg/L maximum
Barium	Potable Aquatic Life	1 mg/L maximum 5 mg/L maximum
Beryllium	Potable Aquatic Life	4.0 µg/L maximum 5.3 µg/L chronic criterion
Bismuth	N/A	
Cadmium	Potable Aquatic Life	5 µg/L (Total) 0.2-0.8 µg/L hardness dependent [GL]=10exp(0.86[log(hardness)]-3.2)
Calcium	Aquatic Life	< 4 sensitive to acid input > 8 low sensitivity to acid input
Chromium	Potable Aquatic Life	50 µg/L l (total) 1 µg/L Cr(VI); 8.9 µg/L Cr(III)
Cobalt	Irrigation	50 µg/L
Copper	Potable Aquatic Life	500 µg/L maximum 0.094*hardness + 2
Iron	Potable Aquatic Life	0.3 mg/L (total) maximum 0.3 mg/L (total) maximum
Lead	Potable Aquatic Life	10 µg/L (total) maximum hardness dependent, $_e$(1.273 1n hardness) - 1.460)
Lithium	No Potable or Aquatic Life Guidelines	
Magnesium	Potable	100-500 mg/L taste >700 mg/L - laxative
Manganese	Potable Aquatic Life	50 µg/L (total) maximum Hardness dependant
Molybdenum	Potable Aquatic Life	0.25 mg/L (total) raw water 2 mg/L
Nickel	Potable Aquatic Life	200 µg/L (total) without treatment 250 µg/L l with treatment 25-180 µg/L hardness dependent
Selenium	Potable Aquatic	10 µg/L maximum 1 µg/L maximum
Silver	Aquatic Life	0.1 µg/L, maximum
Sodium	Potable	20-200 mg/L diet and aesthetics
Strontium	N/A	
Thallium	Potable Aquatic Life	2 µg/L maximum 1.7-6.3 µg/L species dependent
Uranium	Potable Aquatic Life	100 µg/L (total) maximum 300 µg/L maximum
Vanadium	Potable Aquatic Life	0.1 mg/L 6-20 µg/L (Ontario WQO)
Zinc	Potable Aquatic	5 mg/L maximum 33+0.75*(hardness-90)

Appendix C

Analytical Techniques

Bacteria

Indicator bacteria were analysed by Cantest Laboratories Ltd. using the membrane filtration technique outlined in Section E of the British Columbia Laboratory Manual (2003). This method uses a 95% confidence interval.

Bacterial source tracking was carried out by the Pacific Environmental Science Centre (PESC). The technique has been adapted and developed based on the published articles of Dr. Katharine Field from Oregon State University, Corvallis, Oregon (Field et al, 2003). It is a genetic assay that detects 16-S ribosomal genomic DNA from the host-specific intestinal bacterial group *Bacteroides* and thereby identifies the organisms responsible for fecal contamination in water samples. Currently PESC is able to distinguish between fecal contamination from humans, ruminants, pigs, dogs, and elk.

Chemistry

Water chemistry was analysed by Maxxam Analytics Inc. with methods outlined in Table C1.

Table C1. Analytical methods used by Maxxam Analytics Inc. (2006).

Analyses	Laboratory Method	Analytical Method
Alkalinity - Water	ING413 Rev.1.7	Based on SM2320B
Temperature at Arrival		
Chloride by Automated Colourimetry ϕ	BRN-SOP 00116	Based on EPA 325.2
Colour (True)	ING250 Rev 1.0	Based on SM-2120B
Conductance - water	ING413 REV 1.7	Based on SM-2510B
Hardness Total (calculated as CaCO3)		
Hardness (calculated as CaCO3)		
Elements by ICP-AES (dissolved)	ING101 Rev.4.0	Based on EPA 6010B
Elements by ICPMS (dissolved; ultra low) ϕ	ING113 Rev. 1.1	Based on EPA 200.8
Elements by ICPMS (as rec; ultra low) ϕ	ING113 Rev. 1.1	Based on EPA 200.8
Elements by ICP-AES (as received) ϕ	ING101 Rev.4.0	Based on EPA 6010B
Nitrogen (Total)	ING246 Rev.1.4	Based on SM-4500N C
Nitrate+Nitrite (N) (low level	ING233 Rev.4.4	Based on EPA 353.2
pH Water	ING413 Rev.1.7	Based on SM-4500H+B
Sampling Altitude		
Sulphate by Automated Colourimetry ϕ	BRN-SOP 00117	Based on EPA 375.4
Sampling Range		
Total Dissolved Solids (Filt. Residue)	ING443 Rev.5.1	APHA 2540C
Total Dissolved Solids (Filt. Residue)	ING443 Rev.5.1	APHA 2540C
TKN (Calc. TN, N/N) total		
Carbon (Total Organic)	ING211 Rev.2.4	Based on SM-5310C
Phosphorus-P (Total, dissolved) ϕ	ING 237 Rev 5.0	Based on SM-4500P F
Total Phosphorus	ING237 Rev.5.0	SM 4500
Total Suspended Solids ϕ	ING444 Rev.2.3	Based on SM - 2540 D
Total Suspended Solids ϕ	ING444 Rev.2.3	Based on SM - 2540 D
Turbidity	ING 415 Rev.3.1	SM - 2130B