Appendix C – Status and Trends Analyses of Existing Water Quality Data (WQ-1)

SUMMIT
ENVIRONMENTAL CONSULTANTS INC.
A Member of the Associated Engineering Group of Companies

FINAL REPORT

Regional District of Okanagan-Similkameen

Similkameen River Watershed:
Status and Trend Analyses of Existing Water Quality Data (WQ-1)

June 2015

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1 Introduction

1.1 PROJECT BACKGROUND

The Similkameen Valley Planning Society (SVPS) and the Regional District of Okanagan Similkameen (RDOS) are currently developing the Similkameen Watershed Plan (SWP). To support the planning process, RDOS retained Summit Environmental Consultants Inc. (Summit) to complete a number of technical studies to advance the understanding of water resources in the Similkameen watershed. This report presents the results of the water quality technical assessment. It was completed as a component of Phase 2 of the SWP. It was preceded by the Phase 1 study, which was completed in 2014 (Summit 2014).

1.2 PROJECT OBJECTIVES AND TASKS

One of the high priority information gaps identified during the Phase 1 study was an up-to-date understanding of surface water quality in the Similkameen watershed, including how water quality compares to guidelines or standards, how water quality varies within the watershed, and whether or not water quality is changing over time (Summit 2014). Building upon previous water quality assessments, the objective of the Phase 2 water quality study was to address this gap by summarizing the current surface water quality of the Similkameen River (i.e. status assessment) and assessing changes over time (i.e. trends assessment). To meet this objective, the specific tasks that were completed were:

1) Statistical analysis of existing data for the two long-term surface water quality monitoring sites (Princeton and International Border) that are part of the B.C.-Canada Water Quality Monitoring Agreement. The analysis included the following:
    a. Calculation of descriptive statistics;
    b. Comparison of the results to the B.C. water quality guidelines and the Ambient Water Quality Objectives for the Similkameen River Sub-basin;
    c. Assessment of trends in water quality and river flow, including seasonal trends and potential climate change impacts;
    d. Assessment of the relationship between river flow and water quality; and
    e. Assessment of variations in dissolved and total metals, including the role of total suspended sediment concentrations on total metal concentrations.
2) Compilation and summary of surface water quality data from select other sites within the watershed and comparison to the two long-term water quality monitoring sites; and
3) Summary of the surface water quality information that has been collected in recent years by industrial operators in the valley.

2 Methods

2.1 SELECTION OF WATER QUALITY MONITORING SITES

2.1.1 B.C.-Canada Water Quality Monitoring Sites

The Similkameen scoping study report (Summit 2011) and the Phase 1 study (Summit 2014) summarized the results of the information search that was completed to determine how much surface water quality data was in the public domain. The results showed that there are a number of surface water quality monitoring sites in the Similkameen watershed with a significant amount of data. Of particular interest are the two active long-term water quality monitoring sites along the Similkameen River that have a significant amount of data: one near Princeton, and the other near the U.S. border (Table 2-1). These two sites are monitored as part of the B.C.-Canada Water Quality Monitoring Agreement and water quality testing is on-going (i.e. water sampling every two weeks).[1]

The data from these two B.C.-Canada sites are periodically analyzed and presented in summary reports, most recently in 2007 (Swain 2007a, 2007b). Since the release of the last reports, the Copper Mountain Mine has re-opened and there have been several years with relatively low summer flows in the Similkameen River when the concentrations of some metals may be elevated because of limited dilution. Additionally, the focus of the previous B.C.-Canada summary reports has primarily been on how the data compares to provincial water quality guidelines. The reports also include comments on whether trends are visually apparent, but no statistical trend analysis has been completed. Because of these factors, and given the significant amount of available data and importance of the B.C.-Canada sites, the Similkameen at Princeton and Similkameen at International Border sites were selected for detailed analysis (including trend analysis). Select analyses were also completed for a third long-term monitoring site at Hedley (Similkameen River at 20 Mile Creek); however, this site was decommissioned in 1996, so no recent data was available.

Table 2-1 lists the key information for the B.C.-Canada sites included in the study, and Figure 2-1 shows their locations.

[1] The B.C.-Canada Water Quality Monitoring Agreement is an agreement signed in 1985 with the purpose of coordinating and integrating water quality monitoring by Environment Canada and the B.C. Ministry of Environment.

Table 2-1
B.C.-Canada water quality monitoring sites included in the study

Site name	Location	B.C-Canada Site ID	Period of available data
Similkameen River at Princeton	49° 27' 36" N 120° 30' 13" W	BC08NL0001	April 1984 - December 2013
Similkameen River at International Border[1]	49° 04' 46'' N 119° 42' 28'' W	BC08NL0005	October 1979 - December 2013
Similkameen River at 20 Mile Creek	49° 20' 58" N 120° 5' 12" W	BC08NL0008	April 1984 - January 1996

Notes:
1: The Similkameen River at International Border is actually located approximately 10 km north of the International Border, near Chopaka Bridge.

2.1.2 EMS Water Quality Monitoring Sites

In addition to the B.C.-Canada data, water quality data from the provincial Environmental Monitoring System (EMS) Web Reporting database was analyzed for the following key locations in the Similkameen watershed (MOE 2014a):

- Similkameen River near Princeton (upstream and downstream of the wastewater treatment facility outfall);
- Similkameen River near Keremeos (upstream and downstream of the wastewater treatment facility outfall); and
- Hedley Creek downstream of the Nickel Plate Mine.

These sites were selected because they have at least five years of data, they were sampled for parameters of interest given the water uses, and they are indicative of water quality either in important tributaries to the Similkameen River or at locations that provide information on the potential effects of land use, water use, and/or industrial activity. Table 2-2 lists key information for each of the selected monitoring sites, and Figure 2-1 shows their locations.

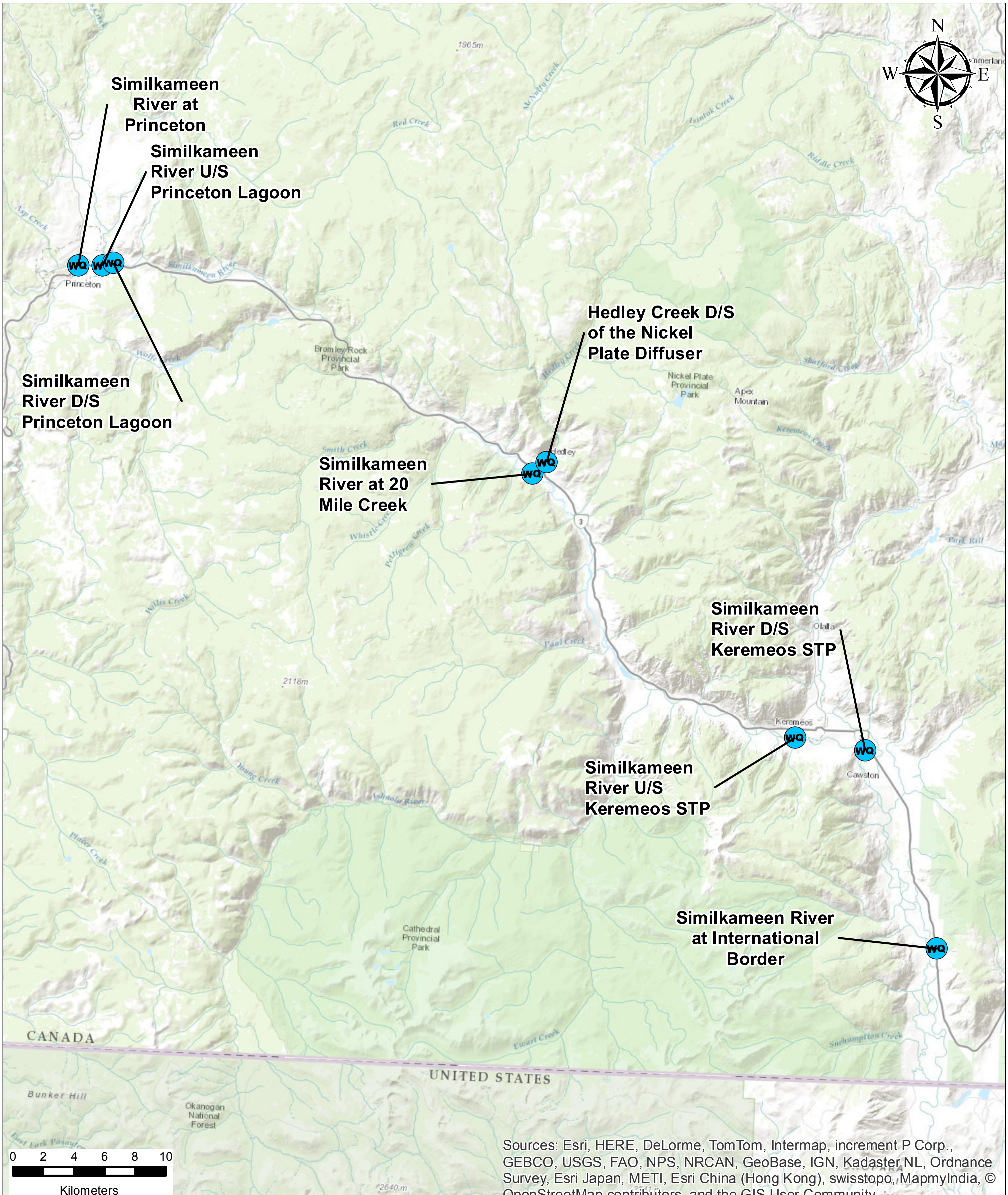

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FIGURE 1-2: WATER QUALITY MONITORING SITES

Regional District of Okanagan Similkameen

Similkameen Valley Watershed Plan Phase 2

Table 2-2
B.C. EMS water quality monitoring sites included in the study

Site name	Location	EMS Site ID	Period of available data
Similkameen River U/S Keremeos STP	49° 12' 1" N 119° 50' 29" W	0500692	February 1979 - August 1993, May 2000[1]
Similkameen River D/S Keremeos STP	49° 11' 40" N 119° 46' 40" W	0500693	February 1979 - September 1993, May 2000, May - June 2002[2]
Similkameen River U/S Princeton Lagoon - PE1236	49° 27' 39" N 120° 28' 55 " W	0500724	July 1979 - September 1993, May - September 2013[3]
Similkameen River D/S Princeton Lagoon - PE1236	49° 27' 45" N 120° 28' 21" W	0500725	July 1979 - August 1993, May - September 2013[4]
Hedley Creek 100 M downstream of the Nickel Plate Diffuser	49° 21' 23" N 120° 4' 28" W	E223874	November 1996 - December 2013

Notes:
1: Sampling occurred primarily during the period 1979 - 1993. However, select samples were also collected in 2000.
2: Sampling occurred primarily during the period 1979 - 1993. However, select samples were also collected in 2000 and 2002.
3: Sampling occurred primarily during the period 1979 - 1993. However, select samples were also collected in 2013.
4: Sampling occurred primarily during the period 1979 - 1993. However, select samples were also collected in 2013.

2.1.3 Water Quality Monitoring near Copper Mountain Mine

Copper Mountain Mine is located along the Similkameen River, approximately 15 km south (and upstream) of Princeton. The mine was re-opened in 2011 after a long period of inactivity. During previous operations, there were two EMS water quality monitoring sites located along the Similkameen River downstream of the mine (EMS site 500418 and 500417). Water quality was tested at these sites between 1972 and 1987. Currently, there is one active EMS site on Wolfe Creek (EMS site 500101), about 5 km northeast of the mine. In addition to the provincial monitoring system, Copper Mountain Mining Corporation carries out environmental monitoring in the vicinity of the mine. According to their 2013 annual report, part of this monitoring included water quality (Copper Mountain Mining Corporation 2013). However, the data from that monitoring is not publically available at this time, and was therefore not included in the study.

2.2 WATER QUALITY ANALYSIS OVERVIEW

Once the data for the sites listed in Tables 2-1 and 2-2 were obtained and formatted, analyses were conducted to assess the current state of water quality in the Similkameen watershed. The analysis included:

- Data screening and normality testing (all sites);
- Calculation of descriptive statistics to provide a summary of the available water quality data (all sites);
- Comparison of water quality results to applicable provincial guidelines and objectives to identify parameters of concern and narrow the focus of additional analysis (all sites);
- Comparison of differences between upstream and downstream water quality to see if effluent discharges from wastewater treatment plants are affecting water quality (at select sites);
- Trend analysis to determine whether water quality and quantity of the Similkameen River is changing over time (at select sites); and
- Assessment of the relationship between river flow and water quality results to identify times of the year when water quality may be of greater concern (at select sites).

The following sections provide a detailed description of the water quality analysis completed for the project. The analyses completed on the B.C.-Canada sites (Table 2-1) are described separately from the EMS sites (Table 2-2) because different analyses were used and different parameters were analyzed. A more detailed analysis was completed for the B.C.-Canada sites, while analysis of the EMS sites was more general and focused on specific parameters only. Note that data screening and normality testing was initially completed for all sites, and is therefore described separately prior to separating the sites. All statistical tests (normality testing, descriptive statistics, trend analysis) were completed using SYSTAT 13.[2]

2.3 DATA ASSEMBLY, SCREENING, AND NORMALITY TESTING

The data assembly, screening, and normality testing included the following main tasks, which were completed for all sites (B.C.-Canada and EMS sites):

1. Data assembly and screening for outliers;
2. Replacement of non-detect values; and
3. Normality testing.

Data assembly and screening for outliers

Water quality data for the B.C.-Canada sites was obtained directly from Environment Canada (P. Chau, personal communication, 2014) and water quality data from the EMS sites was obtained from the online web reporting database (MOE 2014a). The data was then formatted and screened for suspect values (such as values of 999.99 or 0, which appeared periodically throughout the datasets). Data for the B.C.-Canada sites also had to be merged because there were a number of different datasets for the same parameter. For these sites, wherever there had been a change in laboratory, analytical method, or unit in which the data was reported (i.e. mg/L to µg/L), a new dataset was generated. After this screening, we

[2] SYSTAT 13 is a statistical software package that is used for data analysis (www.systat.com).

assumed that the federal and provincial government data were correct and compiled all datasets for each parameter.

Replacement of non-detect values

One of the major challenges for statistical analyses of water quality data is that laboratory results are often reported as below a certain detection limit. In these cases, the laboratory indicates that the result is below a specified concentration, but the actual concentration is not known. These data cannot be discarded because they represent a real observation; however, they must be represented by a real number for statistical analyses. For this assessment, results that were below detection were substituted with 50% of the lowest detection limit in each dataset (as suggested by Helsel and Hirsch [1991]).

Normality testing

Another challenge for statistical analyses of water quality data is that data are often not normally distributed, which means that parametric statistical methods cannot be employed (e.g. linear regression). Statistical tests that assume data is normally distributed are referred to as "parametric" and tests that make no assumptions about the distribution are referred to as "non-parametric". Because these underlying assumptions affect the outcome of the statistical tests, data must first be assessed to determine whether it is normally distributed.

In this case, the B.C.-Canada and EMS water quality data were assessed for normality using the Shapiro-Wilk test in SYSTAT. This test was run randomly on each dataset for several key parameters and the results indicated that in the majority of the cases the data was not normally distributed. Therefore, non-parametric tests were selected for the statistical analyses described in the subsequent sections. Because non-parametric tests make no assumptions about the data distributions, they can also be used for the occasions where the data is normally distributed.

2.4 WATER QUALITY ANALYSIS FOR SELECTED B.C.-CANADA SITES

Once the data screening and normality testing was completed, the following tasks were completed using the entire water quality dataset for the three B.C.-Canada monitoring sites: Similkameen River at Princeton (Princeton site), Similkameen River at International Border (International Border site), and Similkameen River at 20 Mile Creek (20 Mile Creek site).

1. **Calculation of descriptive statistics** (count [n], mean, median, minimum, maximum, 95th percentile, and coefficient of variation [CV]).[3] This was completed for all available data, with the exception of data for ammonia, bicarbonate, carbonate, and dissolved orthophosphorus for the Princeton and the International Border sites because less than 10 measurements for each were available over the period of record.

[3] The coefficient of variation is the ratio of the standard deviation to the mean, and is used to compare variability between sample sets with different means.

2. **Comparison of the 95th percentile concentrations with guidelines,** including the B.C. Approved and Working Water Quality Guidelines (B.C. guidelines) for aquatic life, irrigation, drinking water, and recreation (MOE 2014b) and the Ambient Water Quality Objectives for the Similkameen River Sub-basin (MOE 1981), which include water quality objectives for both the Similkameen River (Similkameen WQO) and Hedley Creek (Hedley Creek WQO). This was completed for the Princeton site, the International Border site, and the 20 Mile Creek site. The goal was to identify parameters of concern and narrow the focus of additional analysis. The B.C.-Canada Water Quality Monitoring Agreement program periodically reviews the data that has been collected for the Princeton and the International Border sites and prepares a water quality assessment. This was last done in 2007 based on the 1976 - 2006 data at the International Border site (Swain 2007a) and based on the 1984 - 2006 data at the Princeton site (Swain 2007b). These reports include a detailed comparison to guidelines, including comments on the frequency of guideline exceedances. The use of 95th percentile concentrations for guideline comparisons in this study was designed to provide an overview of water quality in the Similkameen River and build upon the previous assessments without duplicating them.

3. **Assessment of trends in both water quality and river flow (quantity)** over the period of record for the Princeton site and the International Border site, as well as the relationship between river flow and water quality. This task is further described below. The assessment was not completed for the 20 Mile Creek site because it has been inactive since 1996 and the objective of the trend analysis was to look for more recent changes in water quality within the watershed.

2.4.1 Assessments of Trends

Method details for trend analysis

The purpose of trend analysis is to determine if there is a statistically significant change (increase or decrease) in a parameter of interest over time. Trend analysis is typically used when changes in water quality or quantity (either improvement or degradation) are expected to be subtle or where natural variation makes simple “before and after” comparisons challenging. In these cases, trends cannot necessarily be inferred graphically or by basic linear regression, although the analysis began by plotting the data and fitting a line using the locally weighted scatterplot smoothing (LOWESS) function in SYSTAT.

For this study, trends were assessed using the Mann-Kendall trend test which is a simple, non-parametric, rank-based test for assessing the significance of a trend in a time series. The user specifies either an upward, downward, or two-sided hypothesis.

One of the underlying assumptions of the Mann-Kendall trend test is that consecutive samples are independent of one another, which was assessed in this study using the Autocorrelation function in SYSTAT. For the datasets where the autocorrelation tests showed a low level of serial correlation, standard Mann-Kendall tests were run. For the datasets where seasonally-related autocorrelation was evident, Seasonal Mann-Kendall tests were used to assess trends. For the seasonal assessment, the specified seasons were the months in which the data were collected (i.e. January, February).

Parameters and sites selected for trend analysis

For the Princeton and International Border sites, trend analysis was completed for river flow data and for select water quality parameters as follows:

1. **Water Quality:** The select parameters included key water quality parameters as well as those whose 95th percentile concentrations exceeded guideline levels. Total cadmium was excluded because greater than 20% of the measurements in the dataset were below detection for both sites. Dissolved metals were also excluded because they have only been sampled between May and November, and therefore violate the assumption of a consistent sampling interval. Overall, trend analysis was completed on the following parameters:
   - Conductivity
   - Dissolved oxygen
   - Hardness
   - pH
   - Total dissolved nitrogen
   - Total nitrogen
   - Total phosphorus
   - Turbidity
   - Aluminum (total)
   - Arsenic (total)
   - Chromium (total)
   - Copper (total)
   - Iron (total)
   - Manganese (total)
   - Zinc (total)

2. **Water Temperature:** To determine whether water temperature has changed over time, which could be an indicator of climate change effects, Mann-Kendall trend tests were run on water temperature values for each site. During the data screening task, the data prior to 1990 for both sites was flagged as suspect because the recorded values were consistently above 10°C (even during winter months). Beginning in 1990, water temperature readings became consistent with expected values for the seasons (e.g. near 0°C during the winter). Therefore, data prior to 1990 were excluded from the analysis. For both sites, trend tests were first performed on data from all months and then separately for summer months only (July, August, and September) when the greatest effects of warming would be expected. Separate tests were also run on the calculated averages for July, August, and September to reduce the effects of inconsistent sampling intervals.

3. **River Flow:** To assess whether the magnitude of river flow has changed, trend tests were performed using the mean monthly discharge data for the Princeton site and the International Border site. Discharge data for the Princeton site was available from the Water Survey of Canada (WSC) station on the Similkameen River near Princeton (Station No. 08NL007) (Environment Canada 2015). Discharge data for the International Border site was estimated by scaling the estimated net flows at the International Border (estimated by Summit [2015]) to the International Border site at Chopaka Bridge (approximately 10 km upstream). Use of monthly data instead of daily data reduces the autocorrelation significantly, allowing the standard Mann-Kendall test to be used. For both sites, the tests were run using the means for all months and means for August and September only, which correspond to a period of low flow combined greatest water use. For the Princeton site, the tests were also run using monthly means for recent data only (1981 - 2013). This was not done for the International Border site because the entire period of record is only slightly larger (1979 - 2013) than the recent data period (1981 - 2013).

2.4.2 Assessment of the Relationship between River Flow and Water Quality

The relationship between river flow and water quality was also investigated to assess whether certain parameters may be of higher concern to the watershed during different periods of the year. The average weekly flow and average weekly concentration of select parameters were plotted together to show the typical variation throughout the year. The data from the International Border site was used for this assessment. The relationships between total metals and dissolved metals and total nitrogen and total phosphorus were assessed using the same methods. Correlation analysis was completed for both sites using the Spearman rank-order correlation test, which is a non-parametric test used to assess the strength of association between two variables.

2.5 WATER QUALITY ANALYSIS FOR SELECTED EMS SITES

Once the data screening and normality testing task was complete for the EMS sites listed in Table 2-2, the water quality datasets were analyzed as follows:

1. **Selection of water quality parameters for detailed analysis**. These included parameters of interest for each site (i.e. nutrients for the sites upstream and downstream of the wastewater treatment facility outfalls and routine parameters and metals for the site located downstream of the Nickel Plate Mine). Parameters were only included if there were a significant amount of data (usually $n \geq 30$) and if the results had consistently been above the detection limits (i.e. ≥70% of samples were above detection). Specifically, the parameters listed in Table 2-3 were selected.

2. **Calculation of descriptive statistics for the selected parameters** (count, mean, median, minimum, maximum, 95th percentile, and CV).

3. **Comparison of the 95th percentile concentrations for the selected parameters** with the B.C. guidelines for aquatic life, irrigation, drinking water, and recreation and the Ambient Water Quality Objectives for the Similkameen River Sub-basin (MOE 1981).

4. **Comparison of upstream and downstream water quality** between the Keremeos U/S and D/S site and the Princeton U/S and D/S site using the Kruskal-Wallis statistical test, which is a non-parametric method for determining whether a statistically significant difference exists between two or more groups. The test was used to determine whether the water quality upstream of the wastewater treatment facility outfalls differs from the water quality downstream.

Table 2-3
Parameters from EMS sites selected for statistical analyses

<table>
<tr><th>Site</th><th>Parameters</th></tr>
<tr><td>Similkameen River, upstream of the Keremeos wastewater treatment facility outfall (Keremeos U/S site)</td><td rowspan="4">• Conductivity pH
• Temperature
• Turbidity
• Ammonia (dissolved)
• Nitrate + Nitrite (dissolved)
• Total Kjeldahl Nitrogen
• Nitrogen (total)
• Organic Nitrogen (total)
• Phosphorus (total dissolved)
Phosphorus (total)</td></tr>
<tr><td>Similkameen River, downstream of the Keremeos wastewater treatment facility outfall (Keremeos D/S site)</td></tr>
<tr><td>Similkameen River, upstream of the Princeton wastewater treatment facility outfall (Princeton U/S site)</td></tr>
<tr><td>Similkameen River, downstream of the Princeton wastewater treatment facility outfall (Princeton D/S site)</td></tr>
<tr><td>Hedley Creek, downstream (100 m) of the Nickel Plate Diffuser (Hedley Creek site)</td><td>• Conductivity
• pH
• Sulphate (dissolved)
• Sulphate (total)
• Temperature
• TSS
• Turbidity
• Cyanide
• Aluminum (dissolved)
• Arsenic (dissolved)
• Cobalt (dissolved)
• Copper (dissolved)
• Iron (dissolved)
• Molybdenum (dissolved)
• Lead (dissolved)
• Zinc (dissolved)
• Arsenic (total)
• Copper (total)</td></tr>
</table>

2.6 COMPARISON OF WATER QUALITY BETWEEN B.C.-CANADA SITES AND EMS SITES

The mean concentrations calculated for the B.C.-Canada sites and the EMS sites were compared to determine whether water quality generally appears consistent along the Similkameen River and whether the quality of Hedley Creek is similar to that of the Similkameen River.

3 Results

3.1 B.C.-CANADA WATER QUALITY MONITORING SITES

3.1.1 Descriptive Statistics

The calculated descriptive statistics for the B.C.-Canada sites are listed in Table 3-1. These values represent the baseline information that is available for these parameters as of December 2013. For the calculations, results below the laboratory detection limit were converted to 50% of the lowest detection limit in the dataset for that parameter (as described in Section 2.3). In some cases, a significant number of the values for a particular parameter were below the detection limit and as a result these descriptive statistics are biased by the use of the substituted values. Therefore, Table 3-1 also shows the percentage of detected values for each site and each parameter. Note that the lower the percentage, the more biased the descriptive statistics are because of the high proportion of non-detectable values.

The frequency of water quality sampling has varied for each site and each parameter. Below is a summary of the amount of data available for each site:

- **Similkameen at Princeton (Princeton site):** water quality data is available for the period 1984 to 2013, and monitoring is ongoing. Sampling of total metals and routine parameters has generally occurred once every two weeks. Dissolved metals were added to the program in 2003, with sampling occurring only during the months from May to November.

- **Similkameen at International Border (International Border site):** water quality data is available for the period 1979 to 2013, and monitoring is ongoing. Sampling of total metals and routine parameters has generally occurred once every two weeks. Dissolved metals were also added to the program in 2003, with sampling occurring only during the months from May to November.

- **Similkameen at 20 Mile Creek (20 Mile Creek site):** water quality data is available for the period 1984 to 1996. Routine parameters and total metals were historically sampled. The only dissolved metal that was sampled was magnesium.

Overall, the water quality at the three sites is generally similar, as evidenced by the mean concentrations of analyzed parameters (Table 3-1). The CV values for the parameters at the three sites were similar (about 120-160%) and indicate relatively high variation, likely reflecting variations in suspended sediment concentrations with flow.

Table 3-1
Summary statistics of water quality - B.C.-Canada station

Parameters	Unit	Similkameen at Princeton								Similkameen at International Border								Similkameen River at 20 Mile Creek							
		Count	Percent detected	Mean	Median	Minimum	Maximum	95th percentile	CV	Count	Percent detected	Mean	Median	Minimum	Maximum	95th percentile	CV	Count	Percent detected	Mean	Median	Minimum	Maximum	95th percentile	CV
Conductivity	µs/cm	742	100%	139	146	39	359	203	33%	859	100%	158	170	57	255	216	30%	238	100%	163	173	61	274	229	28%
Hardness (total)	mg/L	690	100%	61	65	22	126	91	33%	694	100%	74	79	25	121	104	31%	185	100%	76	81	28	124	106	29%
Oxygen (dissolved)	mg/L	223	100%	11	11	8	17	8.6	0.1	210.0	1.0	26	10.1	7.4	1200.0	8.1	337%	-	-	-	-	-	-	-	-
pH	pH units	735	100%	7.9	7.9	7.0	9.2	7.5 - 8.2	3%	785	100%	7.9	8.0	6.5	8.4	7.6 - 8.2	3%	232	100%	8.0	8.0	7.4	8.3	7.6 - 8.2	2%
Temperature	°C	741	100%	5.7	5.0	-2.0	21.0	15.0	94%	857	100%	8.7	9.0	-1.0	23.0	18.0	65%	237	100%	10.0	11.0	-1.0	22.2	19.0	60%
Colour (apparent)	REL units	289	79%	10.9	5.0	<5	136	35	123%	423	76%	12.2	5.0	<5	200	35	160%	-	-	-	-	-	-	-	-
Colour (true)	REL units	131	83%	8.6	5.0	<5	50	25	92%	129	80%	8.3	5.0	<2.5	60	25	110%	238	71%	9.6	5.0	<5	80.0	30.0	115%
Turbidity	NTU	743	100%	3.9	0.9	<0.1	157	15	272%	859	100%	5.8	0.8	<0.1	844	22	587%	238	100%	2.6	0.7	0.04	68.0	8	260%
TDS	mg/L	127	100%	100	102	40	180	144	33%	51	100%	105	112	40	207	175	34%	130	100%	114	120	41	209	156	27%
TSS	mg/L	294	61%	15	3.6	<2	344	61	233%	165	72%	36	5.0	<1	680	217	272%	150	21%	11	2.5	<2	290	60	278%
Fecal Coliforms (CFU)	CFU/100 mL	376	59%	26	1	<1	6,900	33	1392%	330	84%	14	6	<1	220	50	174%	-	-	-	-	-	-	-	-
Nitrite (as N)	mg/L	254	37%	0.003	0.001	<0.002	0.017	0.005	88%	247	37%	0.002	0.001	<0.002	0.014	0.005	83%	-	-	-	-	-	-	-	-
Nitrogen (kjedahl dissolved)	mg/L	148	94%	0.08	0.07	<0.02	0.5	0.16	66%	141	98%	0.09	0.08	<0.001	0.5	0.21	64%	-	-	-	-	-	-	-	-
Nitrogen (kjedahl total)	mg/L	127	96%	0.11	0.10	<0.02	0.60	0.26	68%	121	99%	0.12	0.10	<0.02	0.58	0.25	64%	-	-	-	-	-	-	-	-
Nitrogen (dissolved)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	209	97%	0.04	0.03	<0.002	0.26	0.12	-
Nitrogen (NO_3 and NO_2 dissolved)	mg/L	350	76%	0.02	0.01	<0.002	0.13	0.09	138%	461	93%	0.03	0.02	<0.002	0.31	0.09	113%	-	-	-	-	-	-	-	-
Nitrogen (total dissolved)	mg/L	677	99%	0.10	0.08	<0.02	0.56	0.20	64%	734	99%	0.11	0.09	<0.02	0.63	0.21	56%	217	100%	0.10	0.09	0.04	0.38	0.20	49%
Nitrogen (total)	mg/L	139	99%	0.12	0.11	<0.02	0.63	0.28	63%	133	99%	0.14	0.12	<0.02	0.65	0.25	57%	-	-	-	-	-	-	-	-
Phosphate (dissolved)	mg/L	43	33%	0.03	0.03	<0.05	0.05	0.05	36%	43	30%	0.03	0.03	<0.05	0.05	0.05	36%	-	-	-	-	-	-	-	-
Phosphorus (total dissolved)	mg/L	394	82%	0.01	0.004	<0.002	0.08	0.02	119%	375	77%	0.01	0.004	<0.002	0.2	0.01	180%	-	-	-	-	-	-	-	-
Phosphorus (total)	mg/L	550	99%	0.02	0.01	<0.0006	0.56	0.09	233%	654	99%	0.04	0.01	<0.002	1.40	0.17	300%	223	95%	0.02	0.01	<0.002	0.38	0.07	233%
Aluminium (total)	µg/L	639	100%	330	63	2	11,900	1,350	266%	620	100%	466	52	<2	21,200	2,218	334%	135	100%	311	64	7	8,350	1,100	280%
Antimony (total)	µg/L	297	99%	0.062	0.058	<0.001	0.50	0.082	54%	278	100%	0.052	0.048	<0.001	0.27	0.080	43%	-	-	-	-	-	-	-	-
Arsenic (total)	µg/L	692	100%	0.48	0.42	0.10	5.0	0.80	66%	773	100%	1.81	1.30	0.10	42.5	4.4	143%	213	99%	0.43	0.30	<0.1	3.5	0.83	92%
Barium (total)	µg/L	637	100%	24.1	22.7	9.0	149	37.2	47%	621	100%	31.1	29.3	16.3	358	42.3	60%	135	100%	29.7	28.9	18.0	92.7	36.9	29%
Beryllium (total)	µg/L	639	59%	0.017	0.002	<0.001	0.37	0.067	224%	622	58%	0.018	0.002	<0.001	0.64	0.070	261%	135	7%	0.029	0.025	<0.05	0.16	0.052	59%
Bismuth (total)	µg/L	297	50%	0.0025	0.001	<0.001	0.061	0.012	228%	284	57%	0.0054	0.001	<0.001	0.15	0.026	280%	-	-	-	-	-	-	-	-
Boron (total)	µg/L	296	100%	5.7	5.9	1.1	10.2	8.7	33%	284	99%	4.8	4.8	<0.5	8.6	7.4	34%	-	-	-	-	-	-	-	-
Cadmium (total)	µg/L	653	62%	0.045	0.050	<0.002	0.70	0.10	127%	658	60%	0.042	0.006	<0.001	3.1	0.20	374%	148	15%	0.069	0.05	<0.1	0.6	0.15	103%
Cerium (total)	µg/L	269	100%	0.64	0.10	0.005	15.2	3.7	277%	257	100%	0.64	0.081	0.012	16.2	3.3	281%	-	-	-	-	-	-	-	-
Cesium (total)	µg/L	269	100%	0.05	0.02	<0.005	0.97	0.28	222%	257	100%	0.05	0.01	<0.005	0.98	0.24	231%	-	-	-	-	-	-	-	-
Chromium (total)	µg/L	590	82%	0.42	0.18	0.06	10.7	1.6	2.1	587.0	0.8	0.8	0.2	<0.2	35.8	3.0	321%	98	61%	0.41	0.20	<0.2	4.3	1.6	164%
Cobalt (total)	µg/L	638	86%	0.21	0.10	0.01	6.53	0.90	235%	621	98%	0.57	0.31	<0.1	21.5	1.62	219%	135	84%	0.27	0.10	<0.1	6.4	0.94	235%
Copper (total)	µg/L	649	100%	2.85	1.33	0.20	109	8.80	217%	657	99%	2.80	1.10	<0.2	89.8	9.80	223%	148	99%	2.39	1.65	<1	18.6	7.91	107%
Gallium (total)	µg/L	297	100%	0.10	0.017	0.002	2.92	0.59	298%	284	100%	0.15	0.016	0.002	6.28	0.70	351%	-	-	-	-	-	-	-	-
Iron (total)	µg/L	716	100%	316	60	3.6	12,100	1,203	288%	788	100%	581	72	3.4	32,600	2,411	380%	213	100%	303	60	9.6	13,100	1,118	350%
Lanthanum (total)	µg/L	297	100%	0.30	0.06	0.01	7.63	1.68	274%	284	100%	0.38	0.05	0.007	15.1	1.76	327%	-	-	-	-	-	-	-	-
Lead (total)	µg/L	652	68%	0.30	0.06	<0.005	7.69	1.2	2.5	659.0	0.7	0.4	0.1	<0.005	18.0	1.7	3.3	148.0	0.2	0.2	0.1	<0.2	4.3	1.3	191%
Lithium (total)	µg/L	637	100%	0.88	0.76	<0.2	8.70	1.71	74%	622	100%	1.29	1.14	0.10	15.3	2.10	71%	135	100%	1.5	1.4	0.5	5.60	2.52	48%
Manganese (total)	µg/L	717	96%	9.4	2.7	<0.6	380	34.3	2.9	788.0	1.0	20.0	6.6	<0.6	1260.0	75.3	3.3	213.0	0.8	9.5	3.3	<1	277.0	31.7	258%
Molybdenum (total)	µg/L	639	100%	1.0	1.0	<0.1	3.1	1.7	42%	622	100%	1.4	1.5	0.20	3.2	2.2	35%	135	99%	1.3	1.3	<0.1	3.4	1.9	39%
Nickel (total)	µg/L	637	81%	0.41	0.20	<0.02	10.0	1.51	201%	653	80%	0.76	0.20	<0.02	46.1	3.06	334%	135	51%	0.53	0.20	<0.2	15.6	1.86	277%
Niobium (total)	µg/L	269	68%	0.008	0.001	<0.001	0.20	0.03	233%	257	66%	0.01	0.001	<0.001	0.13	0.05	205%	-	-	-	-	-	-	-	-
Platinum (total)	µg/L	269	5%	0.0006	0.0005	<0.001	0.009	0.0008	100%	257	6%	0.0006	0.0005	<0.001	0.003	0.001	33%	-	-	-	-	-	-	-	-
Rubidium (total)	µg/L	297	100%	0.81	0.57	0.27	9.2	2.3	123%	284	100%	0.90	0.66	0.20	14.6	2.3	133%	-	-	-	-	-	-	-	-
Selenium (total)	µg/L	678	90%	0.16	0.14	<0.05	1.50	0.30	69%	764	91%	0.19	0.20	<0.04	0.90	0.36	53%	199	89%	0.2	0.2	<0.1	0.7	0.40	49%
Silver (total)	µg/L	482	58%	0.016	0.001	<0.001	0.20	0.1	2.3	465.0	0.6	0.0	0.0	<0.001	0.3	0.1	233%	-	-	-	-	-	-	-	-
Strontium (total)	µg/L	637	100%	124	130	52	237	175	28%	623	100%	130	138	29	206	174	27%	135	100%	145	149	63	417	197	31%
Thallium (total)	µg/L	297	98%	0.01	0.003	<0.001	0.24	0.04	232%	284	95%	0.01	0.004	<0.001	0.19	0.03	218%	-	-	-	-	-	-	-	-
Tin (total)	µg/L	269	27%	0.005	0.003	<0.005	0.04	0.02	106%	257	14%	0.004	0.003	<0.005	0.09	0.01	162%	-	-	-	-	-	-	-	-
Tungsten (total)	µg/L	269	94%	0.006	0.005	<0.001	0.025	0.013	0.673	257.000	0.953	0.007	0.007	<0.001	0.031	0.013	53%	-	-	-	-	-	-	-	-
Uranium (total)	µg/L	297	100%	0.18	0.17	0.04	1.14	0.29	56%	284	100%	0.46	0.46	0.16	1.52	0.70	36%	-	-	-	-	-	-	-	-
Vanadium (total)	µg/L	639	100%	1.14	0.60	0.20	28.1	3.8	1.8	622.0	1.0	1.7	0.7	0.1	63.3	5.8	2.5	135.0	1.0	1.3	0.7	0.3	25.0	3.7	201%
Yttrium (total)	µg/L	269	100%	0.33	0.08	0.02	7.31	1.61	253%	257	100%	0.33	0.07	0.02	7.75	1.65	248%	-	-	-	-	-	-	-	-
Zinc (total)	µg/L	651	90%	1.40	0.52	<0.05	61.1	5.04	247%	657	91%	2.29	0.60	<0.05	109	8.52	335%	148	84%	1.35	0.60	<0.2	19.5	5.51	174%
Aluminium (dissolved)	µg/L	86	100%	104	26	0.9	2,950	559	329%	90	100%	72	30	0.5	2,080	186	342%	-	-	-	-	-	-	-	-
Antimony (dissolved)	µg/L	33	100%	0.051	0.052	0.038	0.067	0.065	18%	37	100%	0.044	0.044	0.033	0.076	0.056	19%	-	-	-	-	-	-	-	-
Arsenic (dissolved)	µg/L	95	99%	0.46	0.47	<0.2	1.15	0.61	26%	105	100%	0.88	0.68	0.3	5.17	2.11	70%	-	-	-	-	-	-	-	-
Barium (dissolved)	µg/L	86	100%	17.5	14.8	9.3	58.5	29.7	44%	90	100%	21.7	17.9	12.8	50.6	37.3	38%	-	-	-	-	-	-	-	-
Beryllium (dissolved)	µg/L	86	95%	0.006	0.003	<0.001	0.11	0.023	225%	90	97%	0.005	0.004	<0.001	0.075	0.010	166%	-	-	-	-	-	-	-	-
Bismuth (dissolved)	µg/L	86	19%	0.0008	0.0005	<0.001	0.014	0.0026	188%	90	11%	0.0009	0.0005	<0.001	0.023	0.0010	278%	-	-	-	-	-	-	-	-
Boron (dissolved)	µg/L	86	100%	4.9	3.9	0.7	66	7.7	141%	90	98%	3.9	3.6	<0.1	8.2	7.7	46%	-	-	-	-	-	-	-	-
Cadmium (dissolved)	µg/L	86	99%	0.005	0.004	<0.001	0.026	0.009	68%	90	99%	0.006	0.005	<0.001	0.035	0.013	67%	-	-	-	-	-	-	-	-
Cerium (dissolved)	µg/L	78	100%	0.16	0.041	0.002	4.49	0.79	324%	79	100%	0.14	0.065	0.002	3.34	0.33	285%	-	-	-	-	-	-	-	-
Cesium (dissolved)	µg/L	78	97%	0.015	0.008	<0.005	0.27	0.063	211%	79	80%	0.0097	0.006	<0.005	0.22	0.013	261%	-	-	-	-	-	-	-	-
Chromium (dissolved)	µg/L	86	100%	0.16	0.091	0.04	2.75	0.51	191%	90	100%	0.15	0.11	0.06	2.47	0.24	179%	-	-	-	-	-	-	-	-
Cobalt (dissolved)	µg/L	86	100%	0.057	0.026	0.01	1.31	0.23	257%	90	100%	0.16	0.12	0.04	1.37	0.37	99%	-	-	-	-	-	-	-	-
Copper (dissolved)	µg/L	29	100%	1.23	0.80	0.54	8.33	5.47	120%	35	100%	0.95	0.85	0.47	3.75	2.44	61%	-	-	-	-	-	-	-	-
Gallium (dissolved)	µg/L	86	100%	0.02	0.007	0.002	0.68	0.13	316%	90	100%	0.02	0.006	0.002	0.56	0.042	358%	-	-	-	-	-	-	-	-
Iron (dissolved)	µg/L	86	100%	78	15	2.1	2,610	415	379%	90	100%	72	26	3.2	2,530	152	399%	-	-	-	-	-	-	-	-
Lanthanum (dissolved)	µg/L	86	100%	0.10	0.042	0.004	2.09	0.39	247%	90	100%	0.10	0.068	0.003	1.72	0.23	203%	-	-	-	-	-	-	-	-
Lead (dissolved)	µg/L	86	71%	0.04	0.009	<0.005	1.18	0.19	321%	90	81%	0.04	0.014	<0.005	1.15	0.097	327%	-	-	-	-	-	-	-	-
Lithium (dissolved)	µg/L	86	99%	0.47	0.40	<0.2	1.8	0.88	52%	91	100%	0.74	0.60	0.0025	1.8	1.4	47%	-	-	-	-	-	-	-	-
Magnesium (dissolved)	µg/L	53	100%	3,455	3,800	900	6,500	5,130	36%	164	100%	3,784	4,100	900	9,900	5,375	36%	53	100%	3,862	4,300	1,200	6,500	5,230	27%
Manganese (dissolved)	µg/L	86	100%	2.92	1.00	0.43	68.6	11.83	269%	90	100%	4.83	3.09	1.94	79.1	9.36	185%	-	-	-	-	-	-	-	-
Molybdenum (dissolved)	µg/L	86	100%	0.79	0.66	0.43	1.64	1.32	38%	90	100%	1.18	0.93	0.56	2.46	2.33	47%	-	-	-	-	-	-	-	-
Nickel (dissolved)	µg/L	86	99%	0.17	0.10	<0.02	2.07	0.54	140%	90	99%	0.21	0.14	<0.02	2.72	0.35	150%	-	-	-	-	-	-	-	-
Niobium (dissolved)	µg/L	78	62%	0.004	0.001	<0.001	0.051	0.017	195%	79	59%	0.003	0.001	<0.001	0.052	0.009	238%	-	-	-	-	-	-	-	-
Platinum (dissolved)	µg/L	78	12%	0.0006	0.0005	<0.001	0.008	0.001	150%	79	6%	0.001	0.0005	<0.001	0.002	0.001	40%	-	-	-	-	-	-	-	-
Rubidium (dissolved)	µg/L	86	100%	0.49	0.41	0.26	3.6	0.85	78%	90	100%	0.56	0.49	0.35	2.3	0.78	41%	-	-	-	-	-	-	-	-
Selenium (dissolved)	µg/L	95	94%	0.10	0.08	<0.05	0.51	0.21	65%	105	93%	0.13	0.10	<0.05	0.51	0.28	59%	-	-	-	-	-	-	-	-
Silver (dissolved)	µg/L	86	60%	0.002	0.001	<0.001	0.016	0.0067	137%	90	69%	0.002	0.001	<0.001	0.017	0.0049	117%	-	-	-	-	-	-	-	-
Strontium (dissolved)	µg/L	86	100%	92.2	85.2	51.0	173	157	37%	90	100%	96.0	79.6	49.9	180	170	41%	-	-	-	-	-	-	-	-
Sulphur (dissolved)	µg/L	8	-25%	1,813	1,500	<3,000	6,000	6,000	49%	23	65%	3,783	4,000	<3,000	7,000	6,800	52%	-	-	-	-	-	-	-	-
Thallium (dissolved)	µg/L	86	99%	0.0038	0.0025	<0.001	0.043	0.011	134%	90	96%	0.0033	0.0025	<0.001	0.022	0.0085	91%	-	-	-	-	-	-	-	-
Tin (dissolved)	µg/L	78	14%	0.0035	0.0025	<0.005	0.020	0.01	86%	79	11%	0.0036	0.0025	<0.005	0.032	0.009	122%	-	-	-	-	-	-	-	-
Tungsten (dissolved)	µg/L	78	97%	0.01	0.005	<0.001	0.074	0.017	131%	79	96%	0.01	0.006	<0.001	0.025	0.011	56%	-	-	-	-	-	-	-	-
Uranium (dissolved)	µg/L	86	100%	0.09	0.07	0.007	0.27	0.21	64%	90	100%	0.28	0.20	0.085	0.71	0.66	63%	-	-	-	-	-	-	-	-
Vanadium (dissolved)	µg/L	86	100%	0.60	0.45	0.27	5.53	1.38	102%	90	100%	0.61	0.51	0.30	5.54	0.79	96%	-	-	-	-	-	-	-	-
Yttrium (dissolved)	µg/L	78	100%	0.16	0.10	0.016	1.59	0.47	133%	79	100%	0.15	0.12	0.014	1.58	0.33	128%	-	-	-	-	-	-	-	-
Zinc (dissolved)	µg/L	34	41%	0.37	0.10	<0.2	3.99	2.27	193%	39	49%	0.63	0.10	<0.2	9.00	4.26	259%	-	-	-	-	-	-	-	-

Notes:
CV = coefficient of variation
- indicates parameter not analyzed at that site

The following summarizes notable differences in water quality between the sites:

- The International Border site has a higher overall mean concentration of metals than the Princeton site. The largest differences in mean concentrations between the two sites were for total arsenic (International Border site = 1.81 µg/L; Princeton site = 0.48 µg/L), total cobalt (International Border site = 0.57 µg/L; Princeton site = 0.21 µg/L), dissolved cobalt (International Border site = 0.16 µg/L; Princeton site = 0.057 µg/L), total uranium (International Border site = 0.46 µg/L; Princeton site = 0.18 µg/L), and dissolved uranium (International Border site = 0.28 µg/L; Princeton site = 0.09 µg/L). The concentrations of total metals at the 20 Mile Creek site are generally similar to those found at the Princeton site.

- Mean concentrations of nutrients (nitrogen and phosphorus), pH, conductivity, and total dissolved solids between all three sites were similar.

- The mean dissolved oxygen concentration at the International Border site (26 mg/L) was higher than at the Princeton site (11 mg/L). Dissolved oxygen was not measured at the 20 Mile Creek site.

- The mean water temperature at the Princeton site (5.7°C) was lower than the mean water temperature at the International Border site and 20 Mile Creek site (8.7°C and 10.0°C, respectively).

- All three sites have, on average, moderately hard water with a mean hardness between 61 and 76 mg/L. For all three sites the minimum observed hardness was under 30 mg/L, and the maximum hardness greater than 120 mg/L.

3.1.2 Comparison to Water Quality Guidelines

As noted earlier, the 95th percentile concentrations for each parameter were compared with the B.C. guidelines for aquatic life, irrigation, drinking water, and recreation and the Similkameen WQO. Table 3-2 provides a summary of the calculated 95th percentile concentrations for each of the three B.C.-Canada sites, with values exceeding the applicable guidelines highlighted. Note that only parameters with corresponding guidelines are shown in Table 3-2 and calculated descriptive statistics for parameters without guidelines are included in Table 3-1. Additionally, both total and dissolved metals have historically been analyzed at the Princeton and International Border sites, although most water quality guidelines are only for total metals. In these cases, the guideline value for the total metal was also applied to the dissolved metal concentration for interpretive purposes.

The results were generally consistent with the findings of the most recent reports completed as part of the B.C.-Canada Water Quality Monitoring Agreement (Swain 2007a, 2007b). The key findings from the guideline comparison are as follows:

- The water at all three sites is considered moderately hard.
- The water is warm in summer at all three sites, regularly exceeding drinking water aesthetic objectives.
- The 95th percentile concentrations for turbidity ranged from 8 NTU (20 Mile Creek site) to 22 NTU (International Border site). True colour for all three sites exceeded the B.C. drinking water and recreation guidelines.
- The 5th percentile concentration (calculated to indicate the lower level found in water) for dissolved oxygen at both the Princeton and International Border sites was below the minimum specified value for the period of July to March.[4] Dissolved oxygen was not measured at the 20 Mile Creek site.
- Fecal coliforms have been detected frequently at both the Princeton and International Border sites. They were not analyzed at the 20 Mile Creek site. The 90th percentile concentrations for the Princeton and International Border sites were 13 counts/100 mL and 33 counts/100 mL, respectively. The 90th percentile concentration was used in this case because the Similkameen WQO specify that calculation. The counts at both sites exceeded both the Similkameen WQO and the B.C. drinking water guideline (for water that does not receive treatment).
- Total metal concentrations occasionally exceed guidelines. Specifically, the B.C. aquatic life guidelines were exceeded by the 95th percentile concentrations for total chromium and total iron at all three sites and total copper at the Princeton site and International Border site. The Similkameen WQO were exceeded by the 95th percentile concentrations for total copper and total iron at all three sites and total manganese at the International Border site.

[4] The 5th percentile concentration is used to indicate the lower historical levels found in water, and is necessary when comparing to guidelines that specify a minimum value rather than a maximum value.

Table 3-2

Comparison of 95th percentile concentrations to water quality guidelines - B.C.-Canada sites

Parameter	Unit	BC Approved & Working Water Quality Guidelines				Similkameen Water Quality Objectives	95th Percentile Concentration		
		Aquatic life	Irrigation	Drinking water	Recreation		Princeton site	International Border site	20 Mile Creek site
General									
Electrical conductivity	µs/cm	-	700[N1]	-	-	-	203	216	229
pH (5th percentile - 95th percentile)	pH units	6.5 - 9.0[N2]	5.0 - 9.0	6.5 - 8.5	5.0 - 9.0	6.5 - 8.5	7.5 - 8.2	7.6 - 8.2	7.6 - 8.2
Temperature	°C	19[N3]	Narrative[N4]	15	30[N5]	-	15.0	18.0	19.0
Fecal coliforms (90th percentile)	counts/ 100 mL	-[N6]	1000	0[N7]	200	10/100 mL[N8]	13	33	-
Colour (true)	REL units	-[N9]	-	15	15	-	25	25	30
Turbidity	NTU	Narrative[N10]	Narrative[N10]	Narrative[N10]	Narrative[N10]	Narrative[N11]	15	22	8
TSS	mg/L	Narrative[N10]	Narrative[N10]	-	-	Narrative[N12]	61	217	60
TDS	mg/L	-	500[N13]	-	-	-	144	175	156
Nitrate and nitrite (as N)	mg/L	32.8	-	10	10	-	0.09	0.09	-
Nitrite (as N)	mg/L	0.06[N14]	-	1	1	-	0.005	0.005	-
Dissolved oxygen (minimum, 5th percentile)	mg/L	9[N15]	-	-	-	8.0[N16]	8.6	8.1	-
Total metals									
Aluminum (total)	µg/L	-	5000	-	-	-	1350	2218	1100
Antimony (total)	µg/L	20	-	14	-	-	0.082	0.080	-
Arsenic (total)	µg/L	5	100	25	-	50	0.80	4.4	0.83
Barium (total)	µg/L	5000	-	-	-	-	37.2	42.3	36.9
Beryllium (total)	µg/L	5.3	100	4.0	-	-	0.067	0.070	0.052
Boron (total)	µg/L	1200	500[N17]	5000	-	-	8.7	7.4	-
Cadmium (total)	µg/L	-[N18]	5.1	-	-	-	0.10	0.20	0.15
Chromium (total)	µg/L	1[N19]	4.9[N20]	-	-	20	1.6	3.0	1.6
Cobalt (total)	µg/L	110	50	-	-	-	0.90	1.62	0.94
Copper (total)	µg/L	Calc[N21]	200	500	1000	2[N22]	8.80	9.80	7.91
Iron (total)	µg/L	1000	5000	-	-	300	1203	2411	1118
Lead (total)	µg/L	Calc[N23]	200	50	50	Calc[N24]	1.2	1.7	1.3
Lithium (total)	µg/L	870	2500	-	-	-	1.71	2.10	2.52
Manganese (total)	µg/L	Calc[N25]	200	-	-	50	34.3	75.3	31.7
Molybdenum (total)	µg/L	2000	50	250	-	50	1.7	2.2	1.9
Nickel (total)	µg/L	25-65[N26]	200	-	-	65[N27]	1.51	3.06	1.86
Selenium (total)	µg/L	2	10	10	-	-	0.30	0.36	0.40
Silver (total)	µg/L	0.1[N28]	-	-	-	-	0.1	0.1	-
Thallium (total)	µg/L	0.3	-	2	-	-	0.04	0.03	-
Uranium (total)	µg/L	300	10	-	-	100	0.29	0.70	-
Vanadium (total)	µg/L	6	100	-	-	-	3.8	5.8	3.7
Zinc (total)	µg/L	33[N29]	1000[N30]	5000	5000	30	5.04	8.52	5.51
Dissolved metals									
Aluminum (dissolved)	µg/L	100	-	200	200	100	559	186	-
Antimony (dissolved)	µg/L	20	-	14	-	-	0.065	0.056	-
Arsenic (dissolved)	µg/L	5	100	25	-	50	0.61	2.11	-
Barium (dissolved)	µg/L	5000	-	-	-	-	29.7	37.3	-
Beryllium (dissolved)	µg/L	5.3	100	4.0	-	-	0.023	0.010	-
Boron (dissolved)	µg/L	1200	500[N17]	5000	-	-	7.70	7.75	-
Cadmium (dissolved)	µg/L	Calc[N18]	5.1	-	-	-	0.009	0.013	-
Chromium (dissolved)	µg/L	1[N19]	4.9[N20]	-	-	20	0.51	0.24	-
Cobalt (dissolved)	µg/L	110	50	-	-	-	0.23	0.37	-
Copper (dissolved)	µg/L	Calc[N21]	200	500	1000	2[N22]	5.47	2.44	-
Iron (dissolved)	µg/L	350	5000	-	-	300	415	152	-
Lead (dissolved)	µg/L	Calc[N23]	200	50	50	Calc[N24]	0.19	0.097	-
Lithium (dissolved)	µg/L	870	2500	-	-	-	0.88	1.4	-
Manganese (dissolved)	µg/L	Calc[N25]	200	-	-	50	11.83	9.36	-
Molybdenum (dissolved)	µg/L	2000	50	250	-	50	1.32	2.33	-
Nickel (dissolved)	µg/L	25-65[N26]	200	-	-	65[N27]	0.54	0.35	-
Selenium (dissolved)	µg/L	2	10	10	-	-	0.21	0.28	-
Silver (dissolved)	µg/L	0.1[N28]	-	-	-	-	0.0067	0.0049	-
Thallium (dissolved)	µg/L	0.3	-	2	-	-	0.011	0.0085	-
Uranium (dissolved)	µg/L	300	10	-	-	100	0.21	0.66	-
Vanadium (dissolved)	µg/L	6	100	-	-	-	1.38	0.79	-
Zinc (dissolved)	µg/L	33[N29]	1000[N30]	5000	5000	30	2.27	4.26	-

Notes:

- indicates no guideline or not tested

See Appendix A for detailed guideline notes. For guidelines that are calculated based on the local water hardness, the average hardness for each site (Table 3-1) was used.

Legend:

Value exceeds the aquatic life guideline

Value exceeds the irrigation guideline

Value exceeds the drinking water guideline

Value exceeds the recreation guideline

Value exceeds the Similkameen Water Quality Objectives

- Aluminum is one of the few metals to have a guideline maximum specified for the dissolved fraction. The 95th percentile concentration of dissolved aluminum exceeded the Similkameen WQO and the B.C. aquatic life guidelines at the Princeton and International Border sites. The Princeton site concentration also exceeded the B.C. drinking water and recreation guidelines.

- Dissolved copper exceeded the Similkameen WQO for total copper at the Princeton and International Border sites, and dissolved iron exceeded both the Similkameen WQO and the B.C. aquatic life guidelines for total iron at the Princeton site.

3.1.3 Trend Analysis

Water quality

Table 3-3 provides the results of the Mann-Kendall trend tests for each of the selected parameters. It includes the type of test used (Mann-Kendall or Seasonal Mann-Kendall), the time period tested, the selected hypothesis (upward or downward trend), the resulting p-value, and the Sen's slope estimate (which provides an estimate of the magnitude of the trend). Also included is the median and range of days between samples, which provides context for the presence or absence of trends. Note that one of the underlying requirements of the Mann-Kendall (and other) trend tests is that the sampling interval (i.e. days between sampling events) is constant. Accordingly, the higher the variability in the sampling interval, the higher the likelihood of error in estimating trends.

As shown in Table 3-3, the sampling interval for all parameters has been highly variable over time, with samples generally being collected every two weeks with periodic long breaks over which no samples were collected. To assess how this affected the results, Mann-Kendall tests were also run on calculated monthly averages for select parameters, which resulted in significantly more consistent sampling intervals.

As noted in Table 3-3, statistically significant (at $p<0.05$) trends were found for a number of parameters. The majority of the trends were downward, but upward trends were found for total nitrogen, total dissolved nitrogen, turbidity, pH, and total arsenic. As examples of variation over time, Figures 3-1 through 3-4 show the measured concentrations over time of two key parameters (nitrogen and arsenic) for which upward trends were found. The figures show that although statistically significant trends were found, the magnitude of the change over time (i.e. the slope of the graph) is minor. The Sen's slope values in Table 3-3 also show that trends, where present, are slight.

The following bullets provide a short discussion for each of the parameters found to have an upward trend:

- **Nitrogen:** Trend tests were run for total nitrogen and total dissolved nitrogen at both sites, and in all cases a significant upward trend was found. The upward trends for total nitrogen and total dissolved nitrogen were significant over the period 2007-2013 and 1984-2013, respectively. Despite the upward trend, the 95th percentile concentrations for total nitrogen at both sites were relatively low (less than 0.28 mg/L). Total phosphorus levels (another important indicator of nutrient effects) showed no trend at either site.

- **Turbidity:** Upward trends were also found for turbidity at both sites over the entire period of record. Turbidity has been one of the most consistently analyzed parameters at both sites, with sampling generally occurring every 14 days. However, the sampling interval has varied with periodic breaks in testing, and as a result the observed trends are suspect. To further evaluate whether a trend is present, the Mann-Kendall test was re-run using monthly averages and data since 1990 (when sampling became more consistent) which reduced the variation in the sampling interval. These results indicated no trend at either site.

Table 3-3
Presence/absence of trends in water quality

Parameter	Princeton site							International Border site						
	Tested period	**Trend test run**	**Median (range) of sampling interval in days**	**Direction tested**	**p-value**	**Slope estimator**	**Significant trend present[1]**	**Tested period**	**Trend test run**	**Median (range) of sampling interval in days**	**Direction tested**	**p-value**	**Slope estimator**	**Significant trend present[1]**
Conductivity	April 1984 - December 2013	Seasonal Mann-Kendall (all data; seasons as months)	14 (1-651)	Downward	0.114	-0.001	None	October 1979 - December 2013*	Seasonal Mann-Kendall (all data; seasons as months)	14 (1-107)	Downward	0.054	-0.001	None
Dissolved oxygen	September 2005 - December 2013	Seasonal Mann-Kendall (all data; seasons as months)	14 (4-56)	Downward	0.588	<0.0005	None	September 2005 - December 2013	Seasonal Mann-Kendall (all data; seasons as months)	14 (4-76)	Downward	0.143	<0.0005	None
Hardness	March 1988 - December 2013	Seasonal Mann-Kendall (all data; seasons as months)	14 (1-90)	Downward	0.182	<0.0005	None	August 1987 - December 2013	Seasonal Mann-Kendall (all data; seasons as months)	14 (2-43)	Downward	0.001	-0.001	**Downward**
pH	April 1984 - December 2013	Mann-Kendall (all data)	14 (1-1149)	Downward	0.272	<0.0005	None	October 1979 - December 2013	Seasonal Mann-Kendall (all data; seasons as months)	14 (1-372)	Upward	<0.0005	<0.0005	**Upward**
								January 1988 - December 2013	Mann-Kendall		Downward	0.005	<0.0005	**Downward**
Total suspended solids	April 1984 - December 2013	Mann-Kendall (all data)	14 (1-4,593)	Downward	0.095	<0.0005	None	October 1979 - December 2013	Mann-Kendall	14 (1-4,660)	Downward	0.037	<0.0005	**Downward**
Total nitrogen	September 2007 - December 2013	Mann-Kendall (all data)	14 (6-378)	Upward	0.011	<0.0005	**Upward**	September 2007 - December 2013	Mann-Kendall (all data)	14 (4-378)	Upward	<0.0005	<0.0005	**Upward**
Total dissolved nitrogen	April 1984 - December 2013	Mann-Kendall (all data)	14 (1-714)	Upward	<0.0005	<0.0005	**Upward**	August 1981 - December 2013	Mann-Kendall (all data)	14 (1-763)	Upward	<0.0005	<0.0005	**Upward**
Total phosphorus	April 1984 - December 1998; May 2005 - December 2013	Mann-Kendall (all data)	14 (1-2,345)	Downward	0.098	<0.0005	None	August 1981 - December 1998; May 2005 - December 2013	Mann-Kendall (all data)	14 (1-2,331)	Upward	0.185	<0.0005	None
Turbidity	April 1984 - December 2013	Mann-Kendall (all data)	14 (1-651)	Upward	0.033	<0.0005	**Upward**	October 1979 - December 2013*	Mann-Kendall (all data)	14 (1-107)	Upward	0.001	<0.0005	**Upward**
	January 1990 - December 2013	Mann-Kendall (monthly means)		Upward	0.343	<0.0005	None	January 1990 - December 2013	Mann-Kendall (monthly means)		Upward	0.212	<0.0005	None
Aluminum (total)	February 1990 - December 2013	Mann-Kendall (all data)	14 (1-90)	Downward	0.001	-0.003	**Downward**	February 1990 - December 2013	Mann-Kendall (all data)	14 (3-43)	Downward	0.002	-0.002	**Downward**
Arsenic (total)	August 1984 - December 2013	Mann-Kendall (all data)	14 (1-651)	Upward	<0.0005	<0.0005	**Upward**	August 1984 - December 2013	Mann-Kendall (all data)	14 (1-126)	Downward	<0.0005	<0.0005	**Downward**
		Mann-Kendall (monthly means)		Upward	<0.0005	<0.0005	**Upward**		Mann-Kendall (monthly means)			<0.0005	<0.0005	**Downward**
Chromium (total)	January 2001 - December 2013	Mann-Kendall (all data)	14 (4-112)	Downward	0.152	<0.0005	None	January 1991 - December 2013	Mann-Kendall (all data)	14 (4-168)	Downward	0.456	<0.0005	None
Copper (total)	January 1991 - December 2013[2]	Mann-Kendall (all data)	14 (4-90)	Downward	0.017	<0.0005	**Downward**	January 1991 - December 2013[2]	Mann-Kendall (all data)	14 (4-43)	Downward	0.019	<0.0005	**Downward**
		Mann-Kendall (monthly means)			0.023	<0.0005	**Downward**		Mann-Kendall (monthly means)			0.053	<0.0005	None
Iron (total)	August 1984 - December 2013	Mann-Kendall (all data)	14 (1-651)	Downward	0.006	-0.002	**Downward**	August 1984 - December 2013	Mann-Kendall (all data)	14 (1-126)	Downward	0.013	-0.001	**Downward**
		Mann-Kendall (monthly means)		Downward	0.019	-0.003	**Downward**		Mann-Kendall (monthly means)		Downward	0.011	-0.003	**Downward**
Manganese (total)	August 1984 - December 2013	Mann-Kendall (all data)	14 (1-651)	Downward	0.062	<0.0005	None	August 1984 - December 2013	Mann-Kendall (all data)	14 (1-126)	Downward	0.380	<0.0005	None
Zinc (total)	January 1991 - December 2013[2]	Mann-Kendall (all data)	14 (4-90)	Downward	<0.0005	<0.0005	**Downward**	January 1991 - December 2013[2]	Mann-Kendall (all data)	14 (4-43)	Downward	<0.0005	<0.0005	**Downward**

Notes:
1: Trends are considered significant where p ≤ 0.05.
2: Data prior to 1991 was excluded from trend analysis because the values were considered suspect due to preservative vial contamination between 1986 and 1990 (Swain 2007, Phippen 2002).

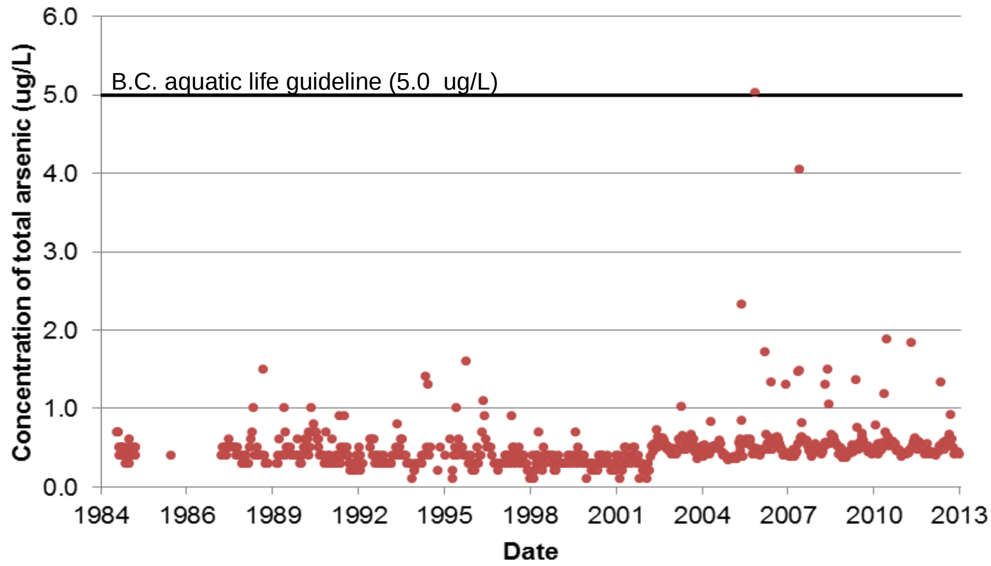

Figure 3-1
Princeton site - total arsenic concentration 1984 - 2013

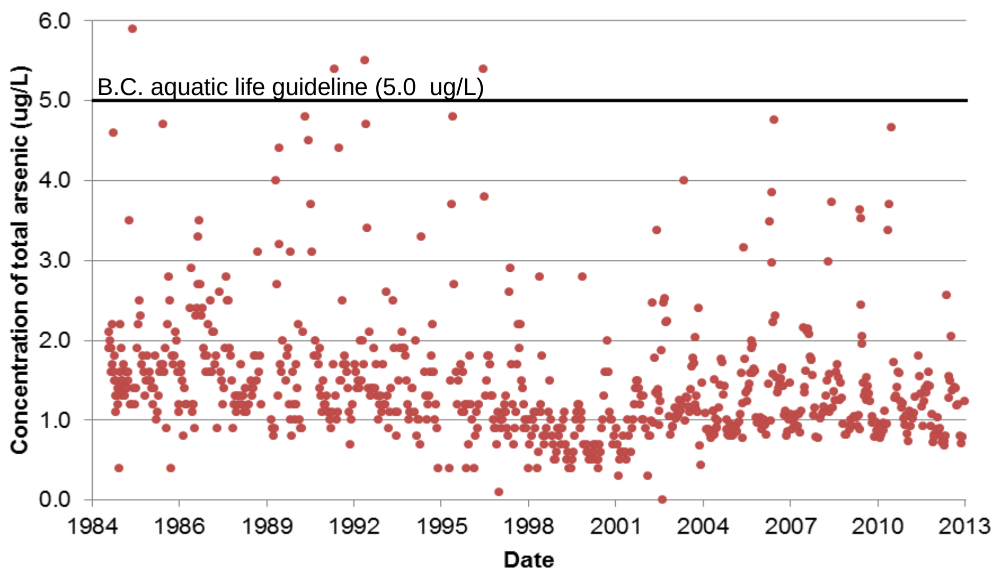

Figure 3-2
International Border site - total arsenic 1979 - 2013

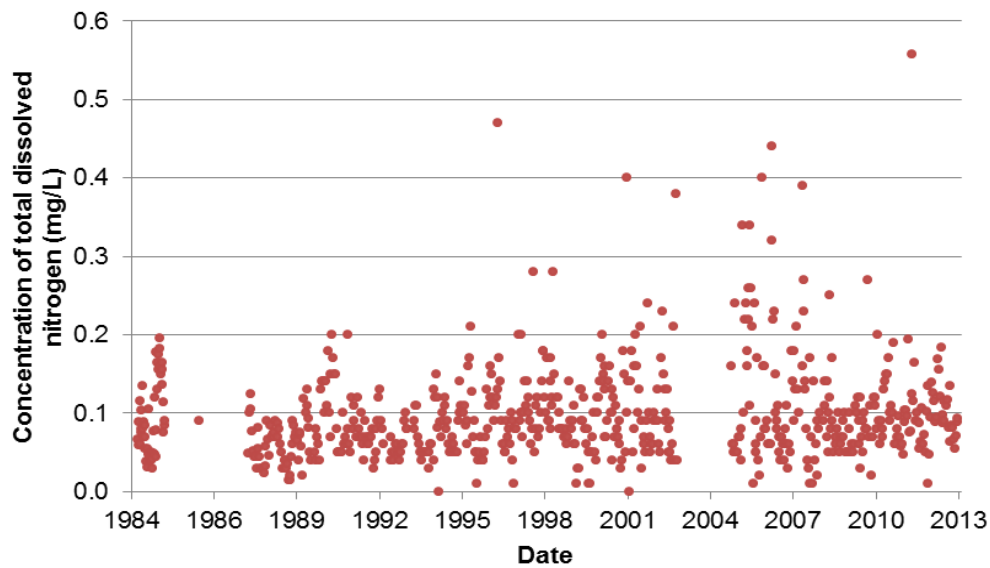

Figure 3-3
Princeton site - total dissolved nitrogen concentration 1984 - 2013

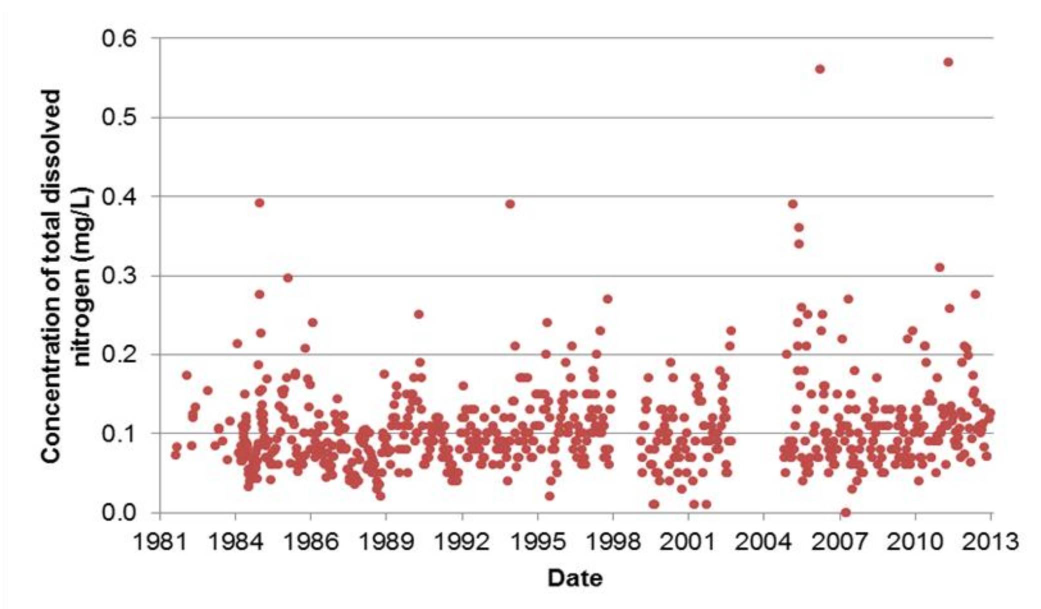

Figure 3-4
International Border site - total dissolved nitrogen concentration 1981 - 2013

- **pH:** Although the pH readings met water quality guidelines, a statistically significant upward trend was found for pH at the International Border site. pH determines the guidelines for certain metals; therefore, changing pH has implications for the potential effects of other parameters. Generally, metal solubility increases as pH decreases, allowing metals to become more mobile. The three lowest pH levels (less than 6.8) at the site occurred during consecutive measurements taken in May 1986, June 1986, and June 1987. To assess whether these anomalously low values in earlier years could be contributing to the upward trend, a Mann-Kendall test was also run using only data since 1988. During this time period, a statistically significant downward trend was found. This shows how the determination of trend can depend upon the sampling interval and period of time selected, and suggests the potential for longer term cycles rather than single-direction trends.

- **Hardness:** A statistically significant downward trend (reduction) was noted for hardness at the International Border site. Hardness does not have a guideline, but is used to calculate the guideline for a number of metals. Therefore, monitoring changes in water hardness is important because it can affect metal toxicity for aquatic life. Hardness is related primarily to the presence of calcium and magnesium cations in solution, which can compete more successfully than other more toxic metals for aquatic life uptake. As a result, guidelines are usually higher for water with higher hardness.

- **Total arsenic:** A statistically significant upward trend was found for total arsenic at the Princeton site, while a statistically significant downward trend was found at the International Border site. To remove some of the potential error associated with inconsistent sampling intervals, trend tests were re-run using monthly averages for both sites. In both cases, a significant trend was still observed. Contributing to the presence of the trends may be anomalously high values in the early dataset for the International Border site, and high values in the more recent dataset for the Princeton site. Additionally, despite the fact that arsenic showed an increasing trend in Princeton and decreasing trend at the International Border, historically higher concentrations have been found at the International Border. The mean arsenic concentration over the period of record was 1.81 µg/L at the International Border, whereas it was 0.48 µg/L at Princeton. In both cases, the mean concentration is within the most stringent guideline of 5 µg/L (B.C. aquatic life guideline).

Statistically significant downward trends were also found for the following parameters:

- Total aluminum (both sites);
- Total copper (both sites);
- Total iron (both sites); and
- Total zinc (both sites).

Because the concentrations of these total metals include both the particulate (i.e. sediment) and dissolved fractions, it is possible that the observed decreases in these total metals reflects changes in TSS. A decreasing trend was found for TSS at the International Border site, whereas the Princeton site had no significant trend. It is important to note, however, that the magnitude of the detected trends are slight (as indicated by Sen's slope) and are unlikely to have any implications for aquatic life or water use. The recommendations section (4.2) outlines suggestions for future monitoring and data analyses.

Water Temperature

Table 3-4 provides the results of the Mann-Kendall trend tests for water temperature. No trends were found for the Princeton site, while a significant downward trend was found for the International Border site when evaluating all months and September water temperatures only.

Table 3-4
Presence/absence of trends in water temperature

Tested period	Princeton site				International Border site			
	Direction tested	p-value	Slope estimator	Significant trend present[1]	Direction tested	p-value	Slope estimator	Significant trend present[1]
All data[2]	Upward	0.210	<0.0005	None	Downward	<0.0005	<0.0005	**Downward**
July data	Upward	0.102	<0.0005	None	Downward	0.093	<0.0005	None
August data	Upward	0.287	<0.0005	None	Downward	0.067	<0.0005	None
September data	Upward	0.506	<0.0005	None	Downward	<0.0005	0.001	**Downward**

Notes:
1: Trends are considered significant where $p \leq 0.05$.
2: Seasonal Mann-Kendall test used to account for serial correlation. The months in which temperatures were recorded were used as the seasons.

River Flow

Table 3-5 provides the results of the Mann-Kendall trend tests on Similkameen River flow (discharge). No significant trends were found with the exception of a downward trend at Similkameen at Princeton when the entire period of record was selected and the Seasonal Mann-Kendall test was used. This suggests a very slight decrease in river discharge at Princeton over the 1945-2013 period. However, no trend was found for the critical low flow months of August and September when the greatest demand on water occurs.

Table 3-5
Presence/absence of trends in river flow

	Tested period	Monthly means	Trend test run	Direction tested	p-value	Slope estimator	Significant trend present[1]
Princeton site[2]	1945 - 2013	All	Mann-Kendall	Downward	0.205	<0.0005	None
			Seasonal Mann-Kendall		0.020	<0.0005	**Downward**
		August	Mann-Kendall	Downward	0.076	<0.0005	None
		September	Mann-Kendall	Downward	0.074	<0.0005	None
	1981-2013	All	Mann-Kendall	Downward	0.836	<0.0005	None
			Seasonal Mann-Kendall		0.921	<0.0005	None
		August	Mann-Kendall	Downward	0.408	<0.0005	None
		September	Mann-Kendall	Downward	0.803	<0.0005	None
International Border site[3]	1981 - 2013	All	Mann-Kendall	Downward	0.624	<0.0005	None
			Seasonal Mann-Kendall		0.809	<0.0005	None
		August	Mann-Kendall	Downward	0.228	<0.0005	None
		September	Mann-Kendall	Downward	0.288	<0.0005	None

Notes:
1: Trends are considered significant where $p \leq 0.05$.
2: Discharge data from Water Survey of Canada Station No. 08NL007.
3: Discharge data estimated by scaling the estimated net flows at the International Border (estimated by Summit [2015]) to the International Border site at Chopaka Bridge (approximately 10 km upstream).

3.1.4 Relationship between River Flow and Water Quality

Figures 3-5 to 3-12 show the relationship between weekly average river discharge and weekly average concentrations of select parameters using all available data from the International Border site. The selected parameters included those where an upward trend was evident (pH, turbidity, total nitrogen, total dissolved nitrogen, and total arsenic) as well as hardness. The findings are as follows:

- As expected, turbidity levels closely follow river flow (Figure 3-5), with high turbidity observed during periods of high flow (when the suspended sediment load is high).

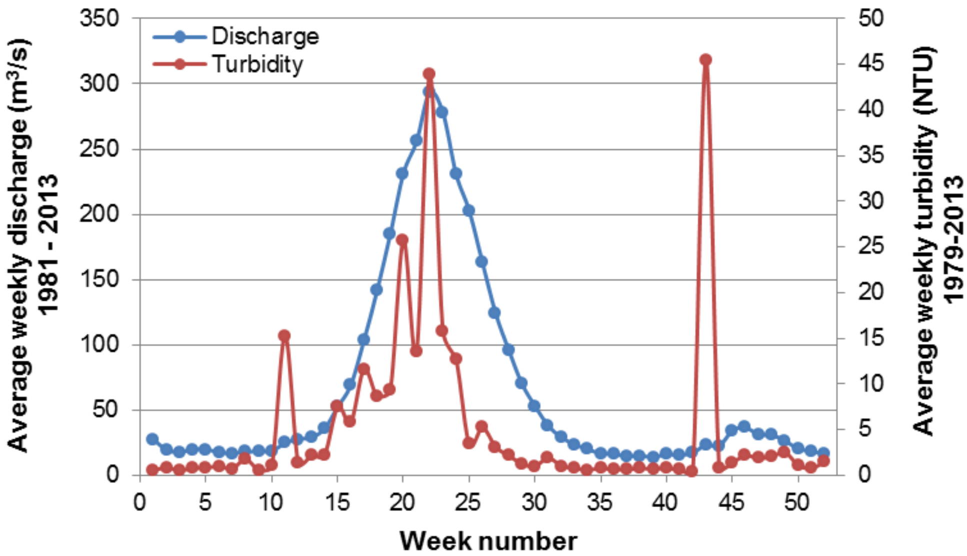

Figure 3-5
Relationship between river discharge and turbidity (International Border site)[5]

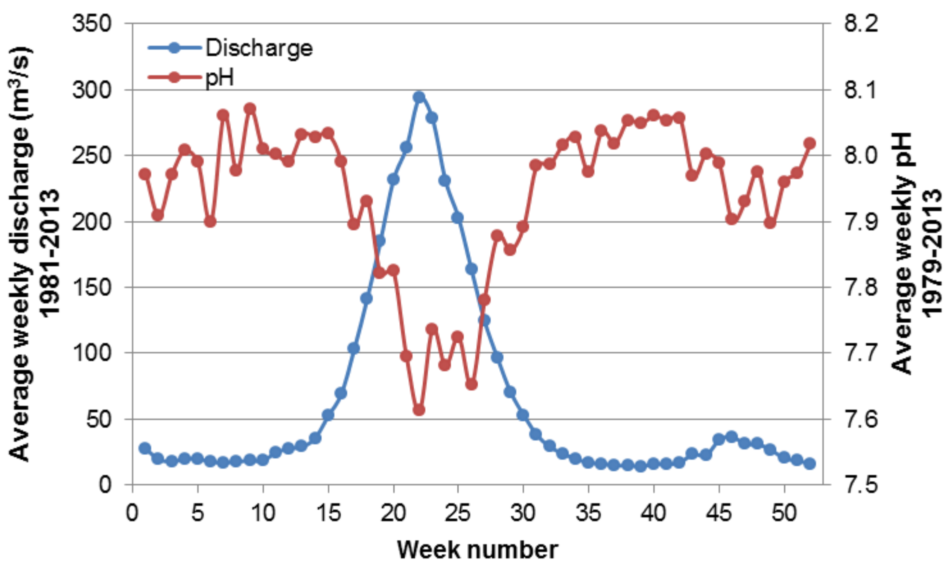

Figure 3-6
Relationship between river discharge and pH (International Border site)

[5] The average turbidity for week 43 (late October) is elevated over the preceding and following weeks because of a single turbidity measurement of 844 NTU on October 21, 2003.

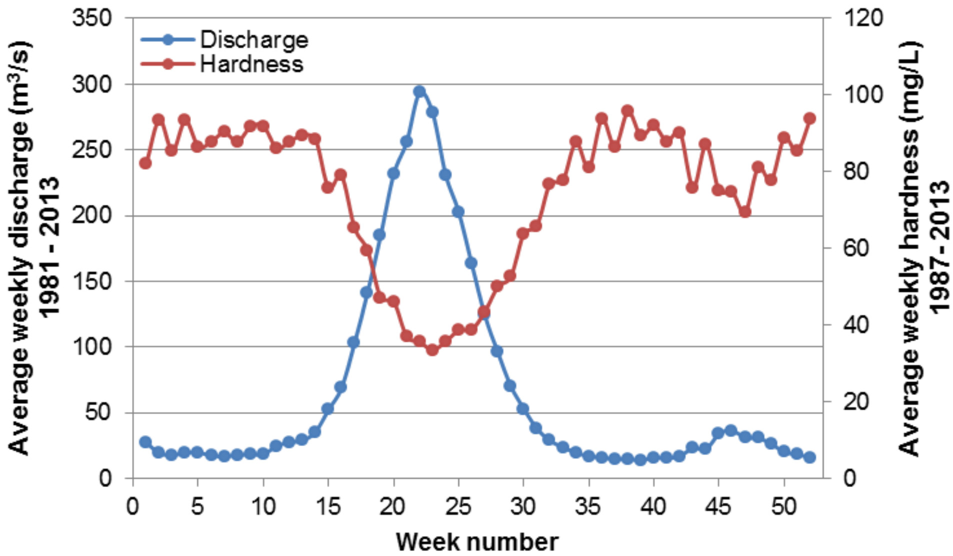

Figure 3-7
Relationship between river discharge and hardness (International Border site)

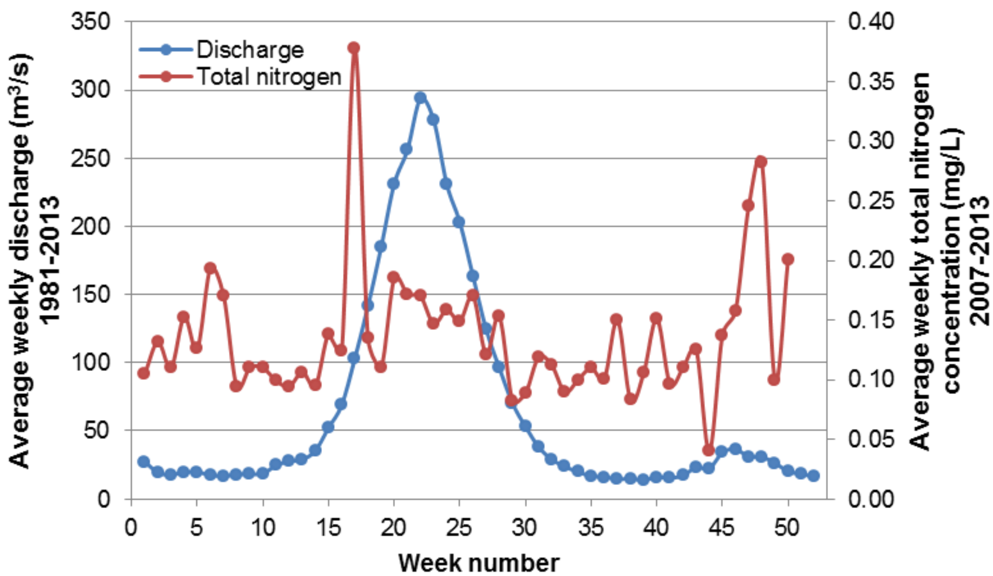

Figure 3-8
Relationship between river discharge and total nitrogen (International Border site)

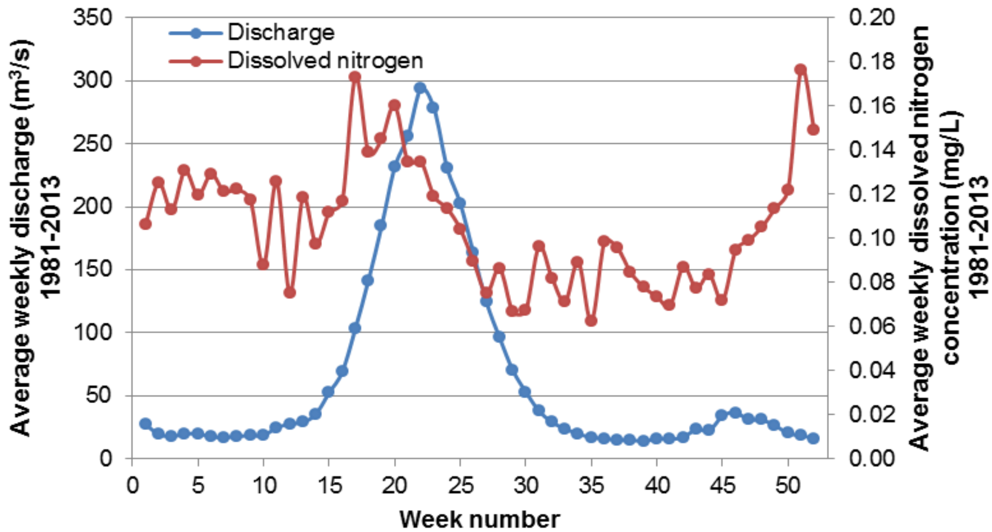

Figure 3-9
Relationship between river discharge and dissolved nitrogen (International Border site)

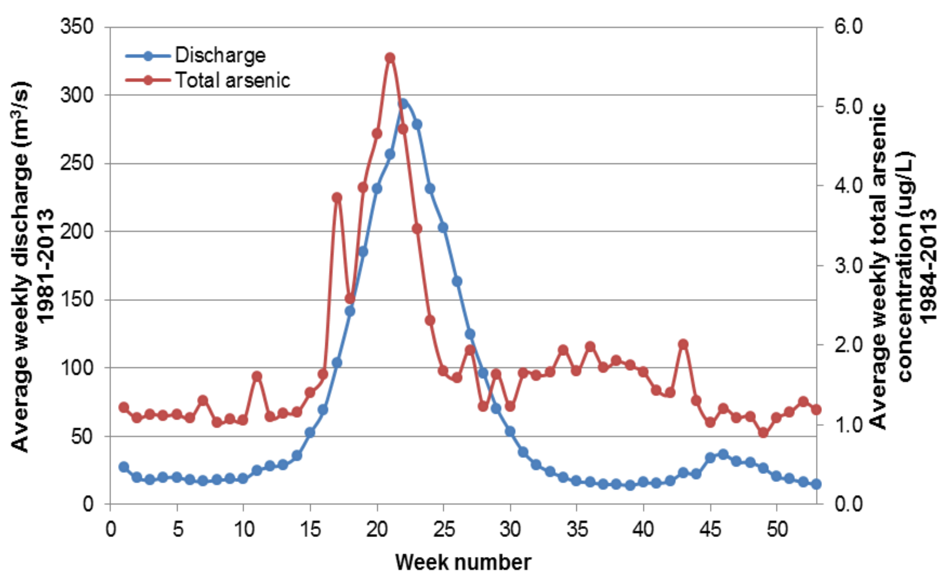

Figure 3-10
Relationship between river discharge and total arsenic (International Border site)

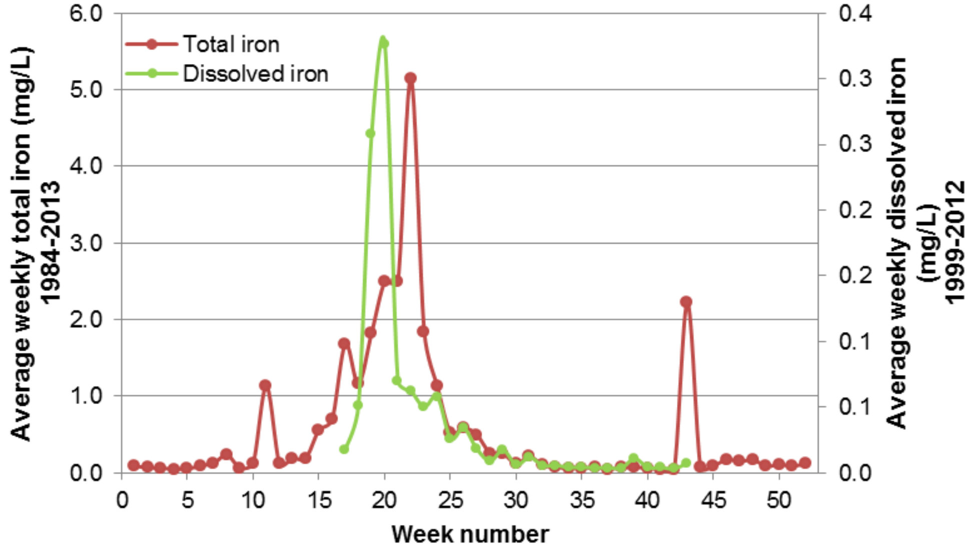

Figure 3-11
Relationship between total iron and dissolved iron (International Border site)

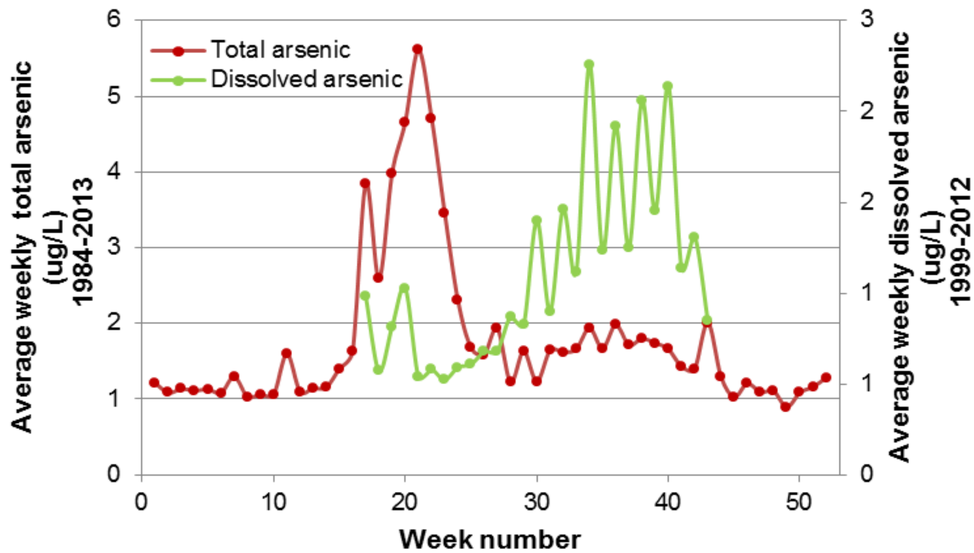

Figure 3-12
Relationship between total arsenic and dissolved arsenic (International Border site)

- pH and water hardness show an inverse relationship to flow, with lower levels occurring during periods of higher flow. Changes in levels of pH and hardness are important because they can affect the toxicity of certain metals, as described in Section 3.1.3. Figures 3-6 and Figure 3-7 show that pH and hardness are typically lower during periods of higher discharge, which also corresponds to periods of higher concentrations of total metals. However, it is important to note that the average pH remains above neutral even during its lowest points, and therefore likely does not have a large effect on the mobility of metals.

- The relationship between total (Figure 3-8) and dissolved nitrogen (Figure 3-9) and flow is less pronounced than that of pH, hardness, and turbidity. Both show more consistent concentrations over the year, with a small increase evident in spring months and a second increase in winter months. Concentrations for both are highly variable over the year.

- Total metals follow the same pattern as river flow and turbidity, with higher concentrations observed during periods of high flow. This is evidenced by Figure 3-10. Other total metals show a similar pattern. This supports the findings by Swain (2007a, 2007b), which suggest that exceedances of the guidelines for total metals are happening primarily when suspended sediment concentrations are high and most of the metals are bound up with sediment and not biologically available.

- Dissolved metals have historically been tested only during May to November; therefore, the yearly relationship between total and dissolved metals could not be established. When weekly average total concentrations are compared with the available weekly dissolved concentrations, the relationship is not consistent. Dissolved copper, chromium, and iron all showed a similar relationship to their corresponding total fraction, with the highest average concentration observed during the high-flow period. Conversely, dissolved arsenic shows an inverse relationship to total arsenic, with lower concentrations occurring during high flow periods and higher concentrations in the lower flow periods following summer. Figures 3-11 and 3-12 show the relationship between total and dissolved iron and total and dissolved arsenic, respectively.

- The ratio of total nitrogen to total phosphorus was also calculated from the 2007 to 2013 dataset for both parameters. The average ratio of nitrogen to phosphorus was 23:1 for both the International Border site and the Princeton site (minimum 0.27:1 and maximum 480:1), indicating that phosphorus is likely the limiting nutrient for biological productivity.

Table 3-6 shows the Spearman's correlation coefficients between select parameters and river flow. The coefficient indicates the strength of the correlation between two variables, and varies between -1 (strong negative correlation) and +1 (strong positive correlation). The results indicate that turbidity, conductivity, and total iron show the strongest correlation with river flow. In the case of conductivity, the relationship is an inverse one where higher conductivity is observed during periods of lower flow.

Table 3-6
Spearman's correlation coefficients for select parameters with river flow

	Princeton site	International Border site
	River flow	River flow
pH	-0.080	-0.580
Temperature	0.143	0.142
Turbidity	0.691	0.779
Conductivity	-0.864	-0.887
Total nitrogen	0.235	0.285
Total dissolved nitrogen	0.155	0.216
Arsenic (total)	0.469	0.078
Copper (total)	0.424	0.681
Iron (total)	0.703	0.866
Manganese (total)	0.559	0.674
Zinc (total)	0.474	0.656

3.2 EMS WATER QUALITY MONITORING SITES

3.2.1 Descriptive Statistics

The calculated descriptive statistics for select parameters for the EMS monitoring sites are listed in Table 3-7. For the calculations, results below the laboratory detection limit were converted to 50% of the lowest detection limit in the dataset for that parameter (as described in Section 2.3). In some cases, a significant number of the values for a particular parameter were below the detection limit and as a result these descriptive statistics are biased by the use of the substituted values. Therefore, Table 3-7 also includes the percentage of detected values for each site and each parameter. The lower the percentage, the more biased the statistics because of the high proportion of non-detectable values.

The number of times individual parameters have been tested and the time period over which they have been analyzed varies for each site and each parameter. Below is a summary of the amount of data available for each site:

- **Similkameen River at Keremeos: Upstream (U/S) and Downstream (D/S) of the wastewater treatment facility outfall:** Data for these two sites is available from 1979 until 1993. There were also a few sampling events in 2000 and 2002. The sampling period over this time has varied greatly and is different for different parameters. For the parameters selected for further analysis, the mean number of samples was 56.

- **Similkameen River at Princeton: Upstream (U/S) and Downstream (D/S) of the wastewater treatment facility outfall:** Sampling occurred at these sites from 1979 until 1993, and then again from May 2013 until September 2013. The sampling interval over this time varied greatly and is different for different parameters. For the nutrient parameters selected for further analysis, the mean number of samples was 60.

- **Hedley Creek 100 m Downstream (D/S) of the Nickel Plate Diffuser:** A significant amount of sampling has been conducted at this site, which is located 100 m downstream of the mine effluent outfall. Data is available from 1996 until 2013, but a number of parameters have only been tested periodically throughout that time period. For the parameters selected for further analysis (which included those with the most amount of data), the mean number of samples was 1,145. Most testing at this site has focused on dissolved metals rather than total metals.

The concentrations of analyzed parameters for the four EMS sites located along the Similkameen River were generally similar, with average CV between sites of 15%. The site upstream of Keremeos had a slightly higher mean pH and water temperature, along with lower turbidity and total dissolved phosphorus, than the other three sites. A statistical comparison between water quality upstream and downstream of the wastewater treatment facility outfalls is included in Section 3.2.3.

Table 3-7
Summary statistics of water quality - EMS sites

Parameters	Unit	Keremeos U/S site								Keremeos D/S site							
		Count	Percent Detected	Mean	Median	Minimum	Maximum	95^{th} Percentile	CV	Count	Percent Detected	Mean	Median	Minimum	Maximum	95^{th} Percentile	CV
Conductivity	µs/cm	72	100%	145	151	51	280	210	34%	84	100%	150	159	53	244	221	34%
pH	pH units	98	100%	8.94	8.10	7.20	8.50	8.46	3%	116	100%	7.99	8.00	7.20	8.50	8.40	4%
Temperature	°C	34	100%	12.8	15.0	0	33.0	20.3	55%	46	100%	11.5	12.0	0	21.0	19.8	54%
Turbidity	NTU	45	100%	6.3	0.8	0.3	62	51	234%	49	100%	7.9	0.9	0.3	60	52	196%
Ammonia (dissolved)	mg/L	66	44%	0.01	0.003	<0.006	0.04	0.01	100%	79	41%	0.01	0.00	<0.006	0.06	0.01	140%
Nitrate + Nitrite (dissolved)	mg/L	53	34%	0.02	0.01	<0.02	0.15	0.08	119%	53	57%	0.03	0.02	<0.02	0.10	0.08	82%
Nitrogen (kjedahl total)	mg/L	52	100%	0.1	0.1	0.01	0.7	0.3	82%	51	100%	0.12	0.09	0.03	0.34	0.32	68%
Nitrogen (total)	mg/L	31	100%	0.15	0.11	0.05	0.69	0.52	82%	31	100%	0.15	0.12	0.03	0.39	0.37	60%
Organic Nitrogen (total)	mg/L	31	100%	0.13	0.10	0.03	0.65	0.48	90%	30	100%	0.13	0.10	0.03	0.33	0.32	66%
Phosphorus (total dissolved)	mg/L	52	69%	0.004	0.004	<0.004	0.01	0.009	75%	52	75%	0.01	0.004	<0.004	0.02	0.01	80%
Phosphorus (total)	mg/L	55	85%	0.02	0.006	<0.004	0.20	0.08	200%	55	89%	0.02	0.01	<0.004	0.20	0.07	200%

Parameters	Unit	Princeton U/S site								Princeton D/S site							
		Count	Percent Detected	Mean	Median	Minimum	Maximum	95^{th} Percentile	CV	Count	Percent Detected	Mean	Median	Minimum	Maximum	95^{th} Percentile	CV
Conductivity	µs/cm	70	100%	126	136	47	210	201	35%	82	100%	146	146	49	350	264	43%
pH	pH units	90	100%	8.09	8.08	7.10	9.80	8.70	5%	114	100%	7.97	8.00	3.60	8.80	8.65	7%
Temperature	°C	31	100%	11.5	13.0	0	22.0	20.8	52%	39	100%	11	14	0	22.0	21.5	60%
Turbidity	NTU	51	100%	8.1	1.0	0.3	80	66	227%	48	100%	7.7	1.0	0.3	81	66	241%
Ammonia (dissolved)	mg/L	63	27%	0.004	0.003	<0.006	0.03	0.01	100%	67	22%	0.01	0.003	<0.006	0.04	0.02	120%
Nitrate + Nitrite (dissolved)	mg/L	63	35%	0.01	0.001	<0.002	0.09	0.06	190%	62	32%	0.01	0.001	<0.002	0.08	0.06	182%
Nitrogen (kjedahl total)	mg/L	62	100%	0.11	0.08	0.02	0.47	0.33	78%	60	100%	0.11	0.09	0.01	0.40	0.31	74%
Nitrogen (total)	mg/L	39	100%	0.11	0.09	0.02	0.38	0.32	65%	38	100%	0.11	0.09	0.02	0.40	0.33	67%
Phosphorus (total dissolved)	mg/L	52	85%	0.01	0.004	<0.004	0.01	0.01	60%	52	81%	0.005	0.005	<0.004	0.012	0.011	60%
Phosphorus (total)	mg/L	62	97%	0.03	0.01	<0.004	0.33	0.19	221%	62	94%	0.025	0.006	<0.004	0.32	0.20	244%

Parameters	Unit	Hedley Creek site							
		Count	Percent Detected	Mean	Median	Minimum	Maximum	95^{th} Percentile	CV
Conductivity	µs/cm	1000	100%	138	130	24	565	268	58%
pH	pH units	976	100%	7.45	7.50	5.85	8.15	6.8 - 7.9	5%
Sulphate (dissolved)	mg/L	91	98%	34	23	<0.5	181	88	93%
Sulphate (total)	mg/L)	4600	100%	35	29	0.64	222	83	78%
Temperature	°C	4563	100%	4.9	3.3	-4.6	18.1	14.0	105%
TSS	mg/L	956	79%	1.5	0.7	0.03	52	5.1	230%
Turbidity	NTU	970	100%	1.4	0.8	0.04	39	3.8	162%
Cyanide	mg/L	980	92%	0.010	0.009	<0.001	0.05	0.02	61%
Cyanide(SAD)+SCN (mg/L)	mg/L	968	92%	0.038	0.022	<0.135	0.30	0.23	145%
Aluminum (dissolved)	µg/L	53	91%	43.0	17.1	5.9	173	160	113%
Arsenic (dissolved)	µg/L	549	28%	0.33	0.25	0.1	2.9	0.7	77%
Cobalt (dissolved)	µg/L	974	96%	14.4	10.4	<0.2	80.0	41.0	96%
Copper (dissolved)	µg/L	963	83%	0.77	0.70	<0.1	6.6	2.0	84%
Iron (dissolved)	µg/L	943	90%	44.2	27.3	<1	418	136	109%
Molybdenum (dissolved)	µg/L	53	91%	1.7	1.3	0.3	6.3	5.0	82%
Zinc (dissolved)	µg/L	933	55%	1.74	0.90	0.10	37	5.90	175%
Arsenic (total)	µg/L	973	35%	0.5	0.3	0.1	20	1.2	224%
Copper (total)	µg/L	981	95%	1.4	1.0	<0.2	130	3.3	304%

Notes:
CV = coefficient of variation
- indicates parameter not analyzed at that site

3.2.2 Comparison to Water Quality Guidelines

As noted earlier, the 95th percentile concentrations for the selected parameters were compared with the B.C. aquatic life, irrigation, drinking water, and recreation guidelines and either the Similkameen WQO or the Hedley Creek WQO depending on the site location. Tables 3-8 and 3-9 provide a summary of the calculated 95th percentile concentrations for each of the sites, with values exceeding the applicable guidelines highlighted. Note that only parameters with guidelines are shown in these tables. Calculated summary concentrations for parameters without guidelines are shown in Table 3-7.

Based on the parameters analyzed, the water quality at the four EMS sites located along the Similkameen River (Keremeos U/S and D/S and Princeton U/S and D/S) is generally good. Water temperatures are warm during summer months, exceeding the aquatic life and drinking water guidelines. The maximum aquatic life guideline for water temperature varies (generally between 10 and 19°C) depending on the distribution of types of fish and the life stage. The 95th percentile value for water temperature for each of the four Similkameen River EMS sites was greater than 20°C. The 95th percentile values for pH at the Princeton sites were just above the B.C. drinking water guideline and the Similkameen WQO, whereas the Keremeos sites were within the guideline range. Other tested parameters were within guideline ranges.

The Hedley Creek site has generally cooler water temperatures and lower concentrations of total suspended solids and turbidity than the sites located along the Similkameen River. The 95th percentile concentration for strong acid dissociable cyanide plus thiocyanate (0.23 mg/L) was just above the B.C. drinking water guideline and the Hedley Creek WQO (both 0.20 mg/L). The Hedley Creek site is located downstream of the Nickel Plate Mine, which has been closed since 1996. The presence of cyanide may be related to past mining operations, as cyanide is used in ore-processing. However, the 95th percentile concentration of strong acid dissociable cyanide plus thiocyanate when including only data since 2008 (i.e. the past five years) was 0.03 mg/L, which suggests conditions may be improving. Weak acid dissociable cyanide, which is used to assess compliance with the B.C. aquatic life guidelines, was below detection 94% of the time it was analyzed. Dissolved aluminum exceeded the B.C. aquatic life guideline and the Hedley Creek WQO, and total copper exceeded the Hedley Creek WQO. Other tested parameters were within guidelines.

Table 3-8
Comparison of 95th percentile concentrations to water quality guidelines - EMS Similkameen River sites

Parameter	Unit	BC Approved and Working Water Quality Guidelines				Similkameen Water Quality Objectives	95th percentile concentration			
		Aquatic life	Irrigation	Drinking water	Recreation		Keremeos U/S site	Keremeos D/S site	Princeton U/S site	Princeton D/S site
Electrical conductivity	µs/cm	-	700[N1]	-	-	-	210	221	201	264
pH (5th percentile - 95th percentile)	pH units	6.5 - 9.0[N2]	5.0 - 9.0	6.5 - 8.5	5.0 - 9.0	6.5 - 8.5	7.5 - 8.5	7.4 - 8.4	**7.6 - 8.7**	**7.3 - 8.7**
Temperature	°C	19[N3]	Narrative[N4]	15	30	-	**20.3**	**19.8**	**20.8**	**21.5**
Turbidity	NTU	Narrative[N5]	Narrative[N5]	Narrative[N5]	Narrative[N5]	Narrative[N5]	51	52	66	66
Ammonia (dissolved)	mg/L	0.68[N6]	-	-	-		0.01	0.01	0.01	0.02
Nitrate and nitrite (as N)	mg/L	32.8	100	10	10	-	0.08	0.08	0.06	0.06
Phosphorus (total)[N7,8]	mg/L	-	-	-	-	-	0.08	0.07	0.19	0.20
Phosphorus (total dissolved)[N7,8]	mg/L	-	-	-	-	-	0.009	0.010	0.011	0.011

Notes:

- indicates no guideline or not tested

See Appendix A for detailed guideline notes. For guidelines that are calculated based on the local water hardness, the average hardness for each site (Table 3-7) was used.

Legend:

Value exceeds the aquatic life guideline

Value exceeds the irrigation guideline

Value exceeds the drinking water guideline

Value exceeds the recreation guideline

Value exceeds the Similkameen Water Quality Objectives

Table 3-9
Comparison of 95th percentile concentrations to water quality guidelines - EMS Hedley Creek site

Parameter	Unit	BC Approved & Working Water Quality Guidelines				Hedley Creek Water Quality Objectives	95th percentile concentration
		Aquatic life	Irrigation	Drinking water	Recreation		Hedley Creek site
Electrical conductivity	µs/cm	NG	700 N1	NG	NG	-	268
pH (5th percentile - 95th percentile)	pH units	6.5 - 9.0 N2	5.0 - 9.0	6.5 - 8.5	5.0 - 9.0	6.5 to 8.5	6.8 - 7.9
Temperature	°C	19 N3	Narrative N4	15	30	-	14.0
Turbidity	NTU	Narrative N5	Narrative N5	Narrative N5	Narrative N5	Narrative N6	3.8
TSS	mg/L	Narrative N5	Narrative N5	NG	NG	Narrative N7	5.1
Sulphate (dissolved)	mg/L	218 N8	NG	500	NG	-	88
Sulphate (total)	mg/L	218 N8	NG	500	NG	-	83
Strong acid dissociable cyanide plus thiocyanate	mg/L	NG N9	NG	0.2	NG	0.20	**0.23**
Aluminum (dissolved)	µg/L	100	NG	200	200	100	160.0
Arsenic (dissolved)	µg/L	5	100	25	NG	50	0.7
Cobalt (dissolved)	µg/L	110	50	NG	NG	-	41
Copper (dissolved)	µg/L	Calc N10	200	500	1000	2 N11	2
Iron (dissolved)	µg/L	350	5000	NG	NG	300	136
Molybdenum (dissolved)	µg/L	2000	50	250	NG	50	5
Zinc (dissolved)	µg/L	33 N12	1000 N13	5000	5000	30	5.9
Arsenic (total)	µg/L	5	100	25	NG	50	1.2
Copper (total)	µg/L	Calc N10	200	500	1000	2 N11	3.3

Notes:

- indicates no guideline or not tested

See Appendix A for detailed guideline notes. For guidelines that are calculated based on the local water hardness, the average hardness for each site (Table 3-7) was used.

Legend:

Value exceeds the aquatic life guideline

Value exceeds the irrigation guideline

Value exceeds the drinking water guideline

Value exceeds the recreation guideline

Value exceeds the Hedley Creek Quality Objectives

3.2.3 Comparison of Upstream and Downstream Water Quality

Tables 3-10 and 3-11 show the median concentrations of parameters indicative of municipal wastewater for locations upstream and downstream of the Keremeos and Princeton wastewater treatment facility outfalls, respectively. The differences in medians between the two sites were tested to see if they were statistically significant using the Kruskal-Wallis test. The results generally show no significant difference (at $p \leq 0.05$) between the upstream and downstream sites. The only difference in medians found to be significant was the one between nitrate-N plus nitrite-N concentrations upstream and downstream of the Keremeos wastewater treatment plant. However, a high proportion of results for nitrate and nitrite were below detection. Overall, the monitoring data suggests that the release of treated wastewater is not having a detectable effect on river water quality.

Table 3-10
Water quality upstream and downstream of the Keremeos wastewater treatment plan

Parameter	Keremeos U/S	Keremeos D/S	Kruskal-Wallis test statistic	p-value	Significant difference ($p \leq 0.05$)
	Median concentration	Median concentration			
Conductivity (µs/cm)	151	159	0.876	0.349	No
pH	8.1	8.0	0.712	0.399	No
Temperature (°C)	15	12	0.253	0.615	No
Turbidity (NTU)	0.8	0.9	1.093	0.296	No
Ammonia-N (dissolved; mg/L)	0.0025	0.0025	0.282	0.595	No
Nitrate + Nitrite-N (dissolved; mg/L)	0.01	0.02	5.482	0.019	**Yes**
Nitrogen (Total Kjeldahl N; mg/L)	0.10	0.09	0.142	0.706	No
Nitrogen (total; mg/L)	0.11	0.12	0.273	0.602	No
Organic nitrogen (total; mg/L)	0.1	0.095	0.038	0.845	No
Phosphorus (total dissolved; mg/L)	0.004	0.004	0.001	0.976	No
Phosphorus (total; mg/L)	0.006	0.006	0.010	0.919	No

Table 3-11
Water quality upstream and downstream of the Princeton wastewater treatment plan

Parameter	Princeton U/S	Princeton D/S	Kruskal-Wallis test statistic	p-value	Significant difference at p ≤ 0.05?
	Median concentration	Median concentration			
Conductivity (µs/cm)	136	146	3.753	0.053	No
pH	8.1	8.0	1.363	0.243	No
Temperature (°C)	13	14	0.068	0.795	No
Turbidity (NTU)	1.0	1.0	0.111	0.739	No
Ammonia-N (dissolved; mg/L)	0.003	0.003	0.364	0.546	No
Nitrate + Nitrite-N (dissolved; mg/L)	0.001	0.001	0.017	0.897	No
Nitrogen (Total Kjeldahl N; mg/L)	0.08	0.089	<0.0005	0.986	No
Nitrogen (total; mg/L)	0.09	0.094	0.003	0.959	No
Phosphorus (total dissolved; mg/L)	0.004	0.005	0.021	0.885	No
Phosphorus (total; mg/L)	0.007	0.006	1.570	0.210	No

3.3 COMPARISON OF WATER QUALITY BETWEEN THE B.C.-CANADA AND EMS SITES

Overall, the water quality between all sites included in the study is relatively similar. This finding is expected, as seven of the eight sites are located on the Similkameen River. The eighth site is located along Hedley Creek. The following summarizes notable similarities and/or differences in average water quality between the sites:

- Average nutrient levels (phosphorus and nitrogen), pH, and electrical conductivity were similar for all sites.

- Average turbidity was also similar, with the lowest levels found at the Hedley Creek site (1.4 NTU) and the highest at the Princeton U/S site (8.1 NTU).

- The sites located along the Similkameen River mainstem had higher average temperatures (5.7°C to 12.8°C) than the site located on Hedley Creek (4.9°C). Of the sites on the mainstem, the lowest average temperature was found at the B.C.-Canada Princeton site (5.7°C). However, the EMS sites located in Princeton just downstream from the B.C.-Canada site had similar average levels (11°C) to those found further downstream.

- Only a few comparisons between B.C.-Canada and EMS sites could be made for metals. No metals were analyzed at the Princeton U/S and D/S site or the Keremeos U/S and D/S site, because they have only been tested sporadically (typically less than 20 measurements). Dissolved metals were not historically tested at the 20 Mile Creek site, and only a few metals were selected for detailed analysis of the Hedley Creek site. However, based on the available data, some differences were observed:

- The average total arsenic concentration was similar between the Princeton site, the 20 Mile Creek site, and the Hedley site ($\leq$0.5 µg/L), whereas the average concentration at the International Border site was higher (1.8 µg/L).
- The average total copper concentration was lower for the Hedley Creek site (1.4 µg/L) than for the B.C.-Canada sites (Princeton, International Border, and 20 Mile Creek; 2.39 - 2.85 µg/L).
- The Hedley Creek site had a lower average dissolved aluminum and dissolved iron concentration (both < 45 µg/L) than the Princeton site and the International Border site (both > 70 µg/L).
- The Hedley Creek site had a higher average dissolved zinc concentration (1.74 µg/L vs. < 0.7 µg/L for the B.C.-Canada sites) and a much higher average dissolved cobalt concentration (14.4 µg/L vs. < 0.2 µg/L for the B.C.-Canada sites).
- The remaining tested metals (dissolved copper, arsenic, and molybdenum) were fairly similar between the three sites.