Assessment of the Upper Fraser Drinking Water Supply: Source Water Characteristics

James Jacklin, March 2004[1]

Introduction

In British Columbia, drinking water quality is becoming a significant public issue. We all want to have confidence in the quality of the water we consume. Its protection is also important to local purveyors, who act as our water suppliers, and to provincial government ministries responsible for water management. Within the Omineca-Peace region of B.C., our most common potable source is ground water, although many communities do make use of rivers, streams or lakes. Our basic drinking water quality is determined by a number of factors including local geology, climate and hydrology. In addition to these, human land use activities such as urbanization, agriculture and forestry, and the pollution they may cause, are becoming increasingly important influences. Environmental managers have a responsibility to control land use development so as to minimise the effects of these activities on source water quality.

The province's Drinking Water Protection Act, enacted in October, 2002, places the responsibility for drinking water quality protection with the B.C. Ministry of Health and local water purveyors. However, through the B.C. Environmental Management Act, the British Columbia Ministry of Environment (MOE) is responsible for managing and regulating activities in watersheds that have a potential to affect water quality. Accordingly, the Ministry plans to take an active role in protecting drinking water quality at its source.

Plate 1. A view of the Upper Fraser pump house where the raw water samples were collected.

MOE implemented a raw water quality and stream sediment monitoring program at selected communities in the Omineca-Peace region in 2002. Community sites were selected using a risk assessment process that considered:

- whether the source supply was surface water or ground water,
- the level of water treatment,
- the population size served,
- the potential for upstream diffuse and point-source pollution,
- the availability of current, high-quality and representative data on each raw water source,
- whether past outbreaks of waterborne illness had been reported,
- the ability/willingness of local purveyors to assist with sampling.

Through this process and with available funding, a total of 18 community water supplies in the Omineca-Peace region were selected for monitoring during 2002/03.

This brief report will summarise water quality data collected from the Upper Fraser raw potable water source (ground water) (Plate 1). The data are compared to current provincial drinking water quality guidelines meant to protect finished water if no treatment other than disinfection is present. This comparison should identify parameters with concentrations that represent a risk to human health. It is intended that this program will lead to the identification of human activities responsible for unacceptable source water quality, and that it will assist water managers to develop measures to improve raw water quality where needed.

[1]A template report was prepared for the author by Todd D. French of TDF Watershed Solutions, Research & Management and Bruce Carmichael, Ministry of Environment.

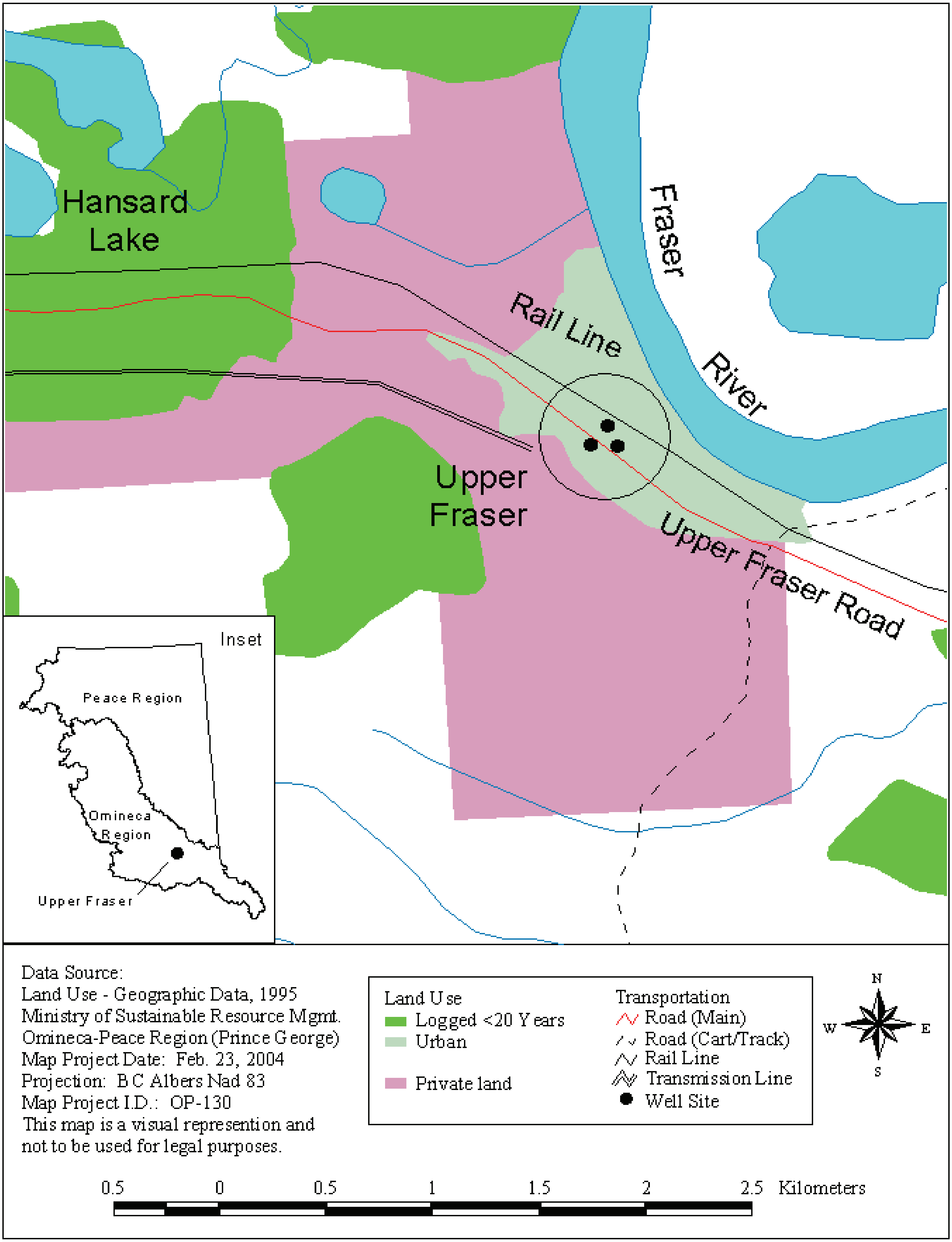

Figure 1. Upper Fraser water wells and nearby land use practices. A 300 m radius surrounds the well indicating the zone where contamination is most probable to occur

Site Description

Watershed Overview

The Community of Upper Fraser is located approximately 50 km northeast of Prince George on Upper Fraser Road. The drinking water supply consists of three wells, located near the lumber mills. This area lies within the Sub-Boreal Spruce biogeoclimatic zone, which is characterized by gently rolling terrain, dense coniferous forests and extremes in the annual temperature range of -40°C to 30°C (B.C. Ministry of Forests, 1998).

The predominant land use in the vicinity of the Upper Fraser wells is urban development and forestry (Figure 1). There are some agricultural activities, however these are located outside the area of most probable contamination (approximately 300 m).

According to Duncan Smith, the drinking water contact for Upper Fraser, there is no water withdrawal data to indicate usage quantities, as the source is not currently metered. Furthermore, there is no available data on the lithology of the wells that would describe the particle size distribution in the ground, and hence relate to the permeability and transmissivity of possible contaminants.

Drinking Water Supply & Treatment

The Community of Upper Fraser draws its domestic water from a ground water supply, consisting of three wells. The wells are located around the pump house, adjacent to the mill. As measured with a GPS unit, the geographic co-ordinates of the pump house are 54.1165N/ 121.9441W. At the pump house, the water goes through a settling pond (Plate 2) and is disinfected with sodium hypochlorite.

Plate 2. A settling pond located beside the Upper Fraser pump house.

According to Mr. Smith, there are no concerns with the current water supply, regarding both quantity and quality.

Materials & Methods

Review of Previous Data

Historical data relevant to the Upper Fraser source water supply assessment have been included in this report. The data were copied from Northern Health Authority (NHA) computer and paper files.

Sample Collection & Analyses for the 2002/03 Water Monitoring Program

Water Quality

An experienced consultant and/or MOE staff member collected water samples in laboratory certified polyethylene bottles for a variety of chemical and bacterial analyses. Representative grab samples were collected from the raw water tap (Plate 3) inside the Upper Fraser pump house (site E249357 - Water Source ID Tag 1322). The chemical results, analytical detection levels and drinking water quality guidelines are provided in Table 1, Appendix A.

Plate 3. A view of the raw water tap where samples were collected.

Bottles used for general ion analyses were rinsed three times with source water prior to sample collection. Metal and bacterial bottles were not rinsed and metal samples were lab preserved. Prior to sampling the raw water tap, the source was flushed for 5 minutes in order to minimize contamination by system piping. Water samples were shipped by overnight courier in coolers with ice packs to CanTest Ltd. (from September 2002-March 2003) and JR Laboratories Inc. (April 2003 to September 2003) for bacteria and PSC Environmental Services Ltd. for chemistry. Bacterial samples were analysed using membrane filtration. Metals analysis made use of ICPMS technology.

Quality Assessment (QA)

To ensure accuracy and precision of data, quality assurance and control (QA/QC) procedures were incorporated into the monitoring program. This included use of rigorous sampling protocols, proper training of field staff, setting of data quality objectives and the submission of QA samples to the lab. Field QA included duplicate and blind blank samples. Blank samples detect contamination introduced in the field and/or in the lab. A comparison of duplicate results measures the effect of combined field error, laboratory error and real between-sample variability. The blind blank and duplicate program accounted for roughly 20% of the overall chemistry and bacterial sample numbers.

Results

Review of Previous Data

Bacteriology

The NHA sampled the Upper Fraser raw water supply three times between April and July 2002. The results of this raw water bacterial program are presented in Table 2. Total coliforms were detected at a concentration of 1 CFU/100 mL on one occasion, however, this exceedance above the detection level may have resulted from a long holding time or warm samples. It is hard to draw conclusions from only two sample dates, although the detection of total coliforms usually indicates that there may be harmful bacteria in the water system and that further sampling is warranted.

Table 2. Historical bacteriological data collected by the NHA from the Upper Fraser raw water supply. All units in CFU/100 mL.

Date	Total Coliforms	Fecal Coliforms
Provincial Guideline	No Provincial Guideline	*≤ 10 CFU/100 mL (90th perc.)*
Apr. 8/02	<1	<1
Jul. 17/02	<1; 1	<1; <1

Water Monitoring Program (2002/03)

Quality Assessment (QA)

The field blank and duplicate results indicate that minimal field or lab contamination of samples with bacteria occurred and that acceptable precision in bacterial sampling and analysis was observed.

The five water chemistry field blank samples that were prepared either the same day or within one day of the Upper Fraser collections tested positive for some parameters. The concentration of most of these parameters was either very close to or less than 5-fold the minimum detectable concentration, an acceptable threshold as per the lab acceptance criteria. Three parameters exceeded these acceptance criteria significantly and are listed in Table 3.

Although the levels of some of these blank results are equal to or greater than the actual concentrations observed in Upper Fraser on some dates, the values are usually well below provincial raw drinking water guidelines by greater than two orders of magnitude. The contamination that did occur may have resulted during the deionization process in the lab or during the transfer of the deionized water between bottles in the field. Regardless, these levels of blank contamination should not limit the comparison of data to water quality guidelines.

Table 3. Blind blank samples that tested strongly positive (≥ 5-fold MDL) for chemical contamination.

Date	Parameter	Measured Concentration	MDL
Jan. 20/03	Copper-Dissolved	0.25 µg/L	0.05 µg/L
Jan. 20/03	Sulfate	14.6 mg/L	0.5 mg/L
Mar. 10/03	Lead-Total	0.19 µg/L	0.01 µg/L

The five water chemistry duplicate samples that were prepared either the same day or within one day of the Upper Fraser collections did have some values outside the lab acceptance criteria of 25% relative percent difference (Table 4, Appendix A). The differences that are present may be due to problems with collection and/or analytical precision. Of particular concern is the imprecision of copper, which occurred well above its respective detection level. All of the parameters that did have differences greater than 25% between the duplicates were well below recommended drinking water guidelines.

Bacteriology

The 2002/03 bacterial data are summarised in Table 5. Drinking water quality guidelines for *E. coli, Enterococci* and fecal coliforms are ≤ 10/100 CFU/100mL (90th perc.), ≤ 3 CFU/100mL (90th perc.), and ≤ 10 CFU/100mL (90th perc.) respectively, in raw water supplies that undergo disinfection only.

Most samples collected from this water supply contained no detectable bacteria. The August 11th sample did have positive results for both total and fecal coliforms. This suggests that fecal material of some sort may be accessing the ground water supply. Although these densities may have been influenced by warm bottle temperatures or a long holding time, these numbers do suggest that future sampling should occur to help identify the contamination source.

Table 5. Results of bacterial analyses for the Upper Fraser raw water supply. Units are CFU/100mL.

Date	Total Coliform	*E. coli*	*Enterococci*	Fecal Coliform
Provincial Guideline	No Provincial Guideline	*≤ 10 CFU/100 mL (90th perc.)*	*≤3 CFU/100 mL (90th perc.)*	*≤ 10 CFU/100 mL (90th perc.)*
Oct. 10/02	<1	<1	<1	<1
Jan. 21/03	<1	<1	<1	<1
Mar. 11/03	<1	<1	<1	<1
Apr. 24/03	<2	<2	<2	<2
May 21/03	<2	<2	<2	<2
Aug. 11/03	**82**	<1	<1	**14**

Care must be taken when comparing these data to B.C. drinking water guidelines, as the recommended guidelines for raw water using disinfection as treatment require five samples to be collected in a 30 day period. 90% of these samples would then need to be over the stated guideline for that guideline to be exceeded. This study did not sample five times in a 30 day period, but rather six times throughout the entire year.

Water Chemistry

In 2002/03, ground water samples were collected on six different dates. The water samples were analysed for 15 general parameters as well as for the ICPMS low level metals package that includes 27 metals in the total form.

Of the chemical parameters tested through the duration of this study, one exceeded the provincial guidelines for raw drinking water and one was of note.

Manganese, Total (µg/L) - The mean manganese concentration was 274 µg/L with a maximum of 491 µg/L, both exceeding the aesthetic objective of 50 µg/L. Manganese can colour water and form colloidal material that can be difficult to remove. High manganese levels occur naturally in many ground water supplies.

Water hardness, which can often be a problem in ground water supplies, had a mean concentration of 227 mg/L $CaCO_3$. This is considered very hard (>180 mg/L $CaCO_3$), above the optimum range of 60-120 mg/L $CaCO_3$ for a drinking water supply. This hardness is due to the presence of calcium and magnesium in the water. Hard water can reduce the toxicity of some metals, but can also leave scale deposits on piping. Some anthropogenic sources that contribute to water hardness are mining and industrial effluents.

The data from 2002/03 indicates that chemical parameters in the Upper Fraser water supply are generally low for drinking water use. There do however appear to be problems regarding both water hardness and manganese levels, both of which probably result from the dissolution of minerals and rocks in the ground.

A complete list of the results as well as their corresponding guideline is attached in Table 1, Appendix A. The 2002/03 raw water quality data is attached in Table 6, Appendix A.

Conclusions & Recommendations

Review of the Upper Fraser ground water data indicates an overall good raw drinking water quality. Most water soluble contaminants were present at concentrations well below drinking water guidelines. The two main parameters of note are hardness and manganese. Elevated hardness levels may cause a problem with the scaling of hot water tanks and pipes. Additionally, there may be aesthetic concerns regarding the abundance of calcium and magnesium. High manganese concentrations can cause black particles to precipitate in pipes, a normal bi-product of the elevated levels. Problems regarding this black precipitate include and unpleasant appearance and taste of the water, as well as allowing an increase in growth of unwanted bacteria that may form slimy layers on system piping (British Columbia Ground Water Association, 2002). High levels of both of these parameters are normal for many ground water sources, mostly resulting from the local geology. There are treatment methods to deal with both water hardness and manganese, however those will not be discussed here.

The bacteria detected during the August, 2003 sampling run indicates that contamination of the water supply by wildlife, range or septic systems may be occurring. Further sampling of this raw water supply may help to identify where these sources are originating from and when the water is unsuitable for human consumption.

Based on the lack of information regarding the well, a 300 m radius is arbitrarily assigned as the zone where contamination is most likely (Mike Wei, Senior Hydrogeologist, MOE, p.c.). Although the lithology profile of the well would be useful (but was not available) in identifying risk through low or high permeability in the ground, the fecal coliforms detected during this study indicate that some contamination of the well has already occurred. Because of this, a site assessment within a 300 m radius of the wells is recommended, which may help indicate where the source of contamination is, and solutions that may help rectify the problem.

Acknowledgements

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Contact Information

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Appendix A

Table 1. 2002/03 sample parameters, summaries of current results and associated B.C. drinking water guidelines.

Parameter	# of Values	Min.	Max.	Mean	Std. Dev.	MDL	D.W. Guideline	Guideline Type
General								
pH	6	8.1	8.3	8.2	0.09	0.1	6.5-8.5	aesthetic objective
Colour (TCU)	6	5	5	5	0.00	5	≤ 15	aesthetic objective
Specific Conductance (µS/cm)	6	403	456	433	22.0	1	≤ 700	maximum acceptable concentration
Turbidity (NTU)	4	0.1	0.51	0.37	0.185	0.1	≤ 5	maximum acceptable concentration
Hardness Total (mg/L)	6	202	244	227	15.3		≤ 500 $CaCO_3$ (Diss.)	aesthetic objective
Alkalinity (mg/L)	6	208	244	229	16.1	0.5		
Residue Non-Filterable (mg/L)	6	4	5	4	0.4	4		
Total Organic Carbon (mg/L)								
TOC	6	1	1.9	1.4	0.4	0.5	≤ 4	maximum, to control THM production
Anions (mg/L)								
Chloride Dissolved	6	0.7	2.3	1.7	0.66	0.5	≤ 250	aesthetic objective
Fluoride Dissolved	6	0.05	0.1	0.08	0.019	0.01	≤ 1.5	maximum acceptable concentration
Bromide Dissolved	6	0.1	0.1	0.1	0.00	0.1		
Nutrients (mg/L)								
Nitrate+Nitrite	6	0.002	0.036	0.010	0.014	0.002	≤ 45 (Nitrate)	maximum acceptable concentration
Phosphorus Total	6	0.021	0.044	0.033	0.016	0.002		
Phosphorus Total-Diss.	6	0.007	0.033	0.020	0.018	0.002		
Sulphate (mg/L)								
Sulphate	6	6.3	10.8	8.2	2.09	0.5	≤ 500	aesthetic objective
Metals Total (ug/L)								
Aluminum-T	6	0.3	1.9	0.6	0.63	0.3	≤ 200 (Diss.)	maximum acceptable concentration
Antimony-T	6	0.005	0.042	0.020	0.017	0.005	≤ 6	interim maximum acceptable concentration
Arsenic-T	6	3.7	10.9	8.1	3.08	0.1	≤ 25	interim maximum acceptable concentration
Barium-T	6	108	137	129	11.5	0.02	≤ 1000	maximum acceptable concentration
Beryllium-T	6	0.02	0.02	0.02	0.000	0.02		
Bismuth-T	6	0.02	0.03	0.02	0.004	0.02		
Cadmium-T	6	0.01	0.11	0.03	0.041	0.01	≤ 5	maximum acceptable concentration
Calcium-T (mg/L)	6	59.3	67.5	62.2	3.00	0.05		
Chromium-T	6	0.2	0.3	0.2	0.04	0.2	≤ 50	maximum acceptable concentration
Cobalt-T	6	0.011	0.467	0.217	0.186	0.005		
Copper-T	6	0.21	0.95	0.73	0.321	0.05	≤ 1000	aesthetic objective
Iron-T (mg/L)	5	0.005	0.18	0.097	0.078	0.005	≤ 0.3	aesthetic objective
Lead-T	6	0.14	1.33	0.407	0.462	0.01	≤ 10	maximum acceptable concentration
Lithium-T	6	0.05	4.29	2.28	1.357	0.05		
Magnesium-T (mg/L)	6	10.9	21.1	17.4	4.67	0.05	≤ 100 (Diss.)	aesthetic objective
Manganese-T	6	5.38	491	274	212.4	0.008	≤ 50	aesthetic objective
Molybdenum-T	6	1.15	2.51	1.99	0.638	0.05	≤ 250	maximum acceptable concentration
Nickel-T	6	0.05	0.05	0.05	0.000	0.05		
Selenium-T	6	0.2	0.2	0.2	0.00	0.2	≤ 10	maximum acceptable concentration
Silver-T	6	0.02	0.02	0.02	0.000	0.02		
Sodium-T (mg/L)	5	4.96	9.14	6.7	1.52	0.05	≤ 200	aesthetic objective
Strontium-T	6	716	859	770	51.9	0.005		
Thallium-T	6	0.002	0.008	0.006	0.002	0.002	≤ 2	maximum acceptable concentration
Tin-T	6	0.01	0.02	0.01	0.005	0.01		
Uranium-T	6	0.7	1.49	1.22	0.347	0.002	≤ 100	maximum acceptable concentration
Vanadium-T	6	0.18	1.58	0.80	0.549	0.06	≤ 100	maximum acceptable concentration
Zinc-T	6	2.6	131	46.2	57.26	0.1	≤ 5000	aesthetic objective

Table 4. Duplicate samples that exceeded precision acceptability criteria (≤25% difference when >5-fold MDL). All concentrations in µg/L.

Parameter	MDL (µg/L)	January/03			April/03			May/03			August/03		
		Conc. 1	Conc. 2	RPD %	Conc. 1	Conc. 2	RPD %	Conc. 1	Conc. 2	RPD %	Conc. 1	Conc. 2	RPD %
Copper-T	0.05				0.36	0.78	**74**				15	6.7	**76**
Copper-D	0.05										8.53	2.75	**102**
Lead-T	0.01				< 0.01	0.09	**160**						
Lead-D	0.01										0.52	0.39	**29**
Lithium-T	0.05							0.22	0.29	**27**			
Lithium-D	0.05	0.69	2.15	**1.42**									
Manganese-T	0.008										1.86	1.42	**27**
Tin-T	0.01	0.01	0.1	**164**							0.1	0.06	**50**
Zinc-T	0.1	< 0.1	1.7	**178**	0.9	1.4	**44**						
Zinc-D	0.1	< 0.1	0.8	**156**									

RPD %=Relative Percent Difference
**Data are presented for the purpose of batch specific QA assessment. Most QA samples were not collected at Upper Fraser.*

Table 6. 2002/03 raw water quality data collected from the Upper Fraser drinking water supply.

Date	Total Coliform (CFU/100mL)	Fecal Coliform (CFU/100mL)	Enterococci (CFU/100mL)	E. Coli (CFU/100mL)	pH (pH Units)
10-Oct-02	<1	<1	<1	<1	8.3
21-Jan-03	<1	<1	<1	<1	8.1
11-Mar-03	<1	<1	<1	<1	8.1
24-Apr-03	<2	<2	<2	<2	8.3
21-May-03	<2	<2	<2	<2	8.2
11-Aug-03	82	14	<1	<1	8.2

True Colour (Col. Unit)	Specific Conductance (µS/cm)	Residues - NonFilt. (mg/L)	Turbidity (NTU)	Hardness - Total (mg/L)	Alkalinity - T as $CaCO_3$ (mg/L)
5	456	<4		228	242
5	408	5		218	210
<5	447	<4	0.51	244	244
<5	439	<4	0.45	232	236
<5	403	<4	<0.1	202	208
<5	445	<4	0.43	239	236

Bromide - Diss. (mg/L)	Chloride - Diss. (mg/L)	Fluoride - Diss. (mg/L)	Carbon - Tot. Org. (mg/L)	$NO_2 + NO_3$ (mg/L)	Phosphorus - Tot. Diss. (mg/L)
<0.1	2.3	0.09	1.2	<0.002	
<0.1	1.1	0.06	1.9	0.036	
<0.1	2.1	0.1	1.7	<0.002	
<0.1	2.2	0.07	1	0.003	
<0.1	0.7	0.05	1.6	0.014	0.007
<0.1	1.9	0.08	1	<0.002	0.033

Phosphorus - Tot. (mg/L)	Sulfate (mg/L)	Aluminum - Tot. (µg/L)	Antimony - Tot. (µg/L)	Arsenic - Tot. (µg/L)	Barium - Tot. (µg/L)
	6.6	<0.3	<0.005	9.6	131
	10.8	<0.3	0.042	4.7	108
	8.1	0.5	0.006	10.9	137
	6.7	<0.3	0.009	10.1	137
0.021	10.8	0.5	0.04	3.7	123
0.044	6.3	1.9	0.02	9.7	136

Beryllium - Tot. (µg/L)	Bismuth - Tot. (µg/L)	Cadmium - Tot. (µg/L)	Calcium - Tot. (mg/L)	Chromium - Tot. (µg/L)	Cobalt - Tot. (µg/L)
<0.02	<0.02	<0.01	59.3	0.3	0.137
<0.02	<0.02	0.11	67.5	<0.2	0.027
<0.02	<0.02	0.01	62.8	<0.2	0.337
<0.02	0.03	0.01	59.8	<0.2	0.321
<0.02	<0.02	0.01	63.1	<0.2	0.011
<0.02	<0.02	0.01	60.9	<0.2	0.467

Copper - Tot. (µg/L)	Iron - Tot. (mg/L)	Lead - Tot. (µg/L)	Lithium - Tot. (µg/L)	Magnesium - Tot. (mg/L)	Manganese - Tot. (µg/L)
0.21		0.14	<0.05	19.3	364
0.95	0.034	0.2	2.64	12	7.14
0.44	0.18	0.14	2.44	21.1	385
0.93	0.167	0.39	2.17	20.1	395
0.95	0.005	0.24	4.29	10.9	5.38
0.88	0.099	1.33	2.11	21	491

Molybdenum - Tot. (µg/L)	Nickel - Tot. (µg/L)	Selenium - Tot. (µg/L)	Silver - Tot. (µg/L)	Sodium - Tot. (mg/L)	Strontium - Tot. (µg/L)
2.2	<0.05	<0.2	<0.02		716
1.15	<0.05	<0.2	<0.02	4.96	779
2.44	<0.05	<0.2	<0.02	6.53	727
2.46	<0.05	<0.2	<0.02	6.24	751
1.22	<0.05	<0.2	<0.02	9.14	859
2.51	<0.05	<0.2	<0.02	6.63	789

Thallium - Tot. (µg/L)	Tin - Tot. (µg/L)	Uranium - Tot. (µg/L)	Vanadium - Tot. (µg/L)	Zinc - Tot. (µg/L)
<0.002	<0.01	1.44	1.3	2.6
0.008	0.02	0.854	0.81	131
0.007	<0.01	1.43	1.58	7.6
0.005	<0.01	1.49	0.31	6.9
0.005	<0.01	0.7	0.64	107
0.006	0.02	1.4	0.18	22.3