Assessment of the District of Chetwynd (Pine River) Drinking Water Supply: Source Water Characteristics

James Jacklin, August 2005

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 an active role in protecting drinking water quality at its source.

Plate 1. An upstream view of the Pine River at the District of Chetwynd lowlift station.

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 raw source water,
- 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. The District of Chetwynd ground water supply was monitored in 2002/03, and a ground water brochure is available on request. The Pine River water supply was subsequently monitored from 2003-05 and is the subject of this brochure.

This brief report will summarise water quality data collected from the District of Chetwynd's raw potable water source, the Pine River (Plate 1). The data are compared to current provincial drinking water quality guidelines. 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 supply water quality, and that it will assist water managers to develop measures to improve raw water quality where needed.

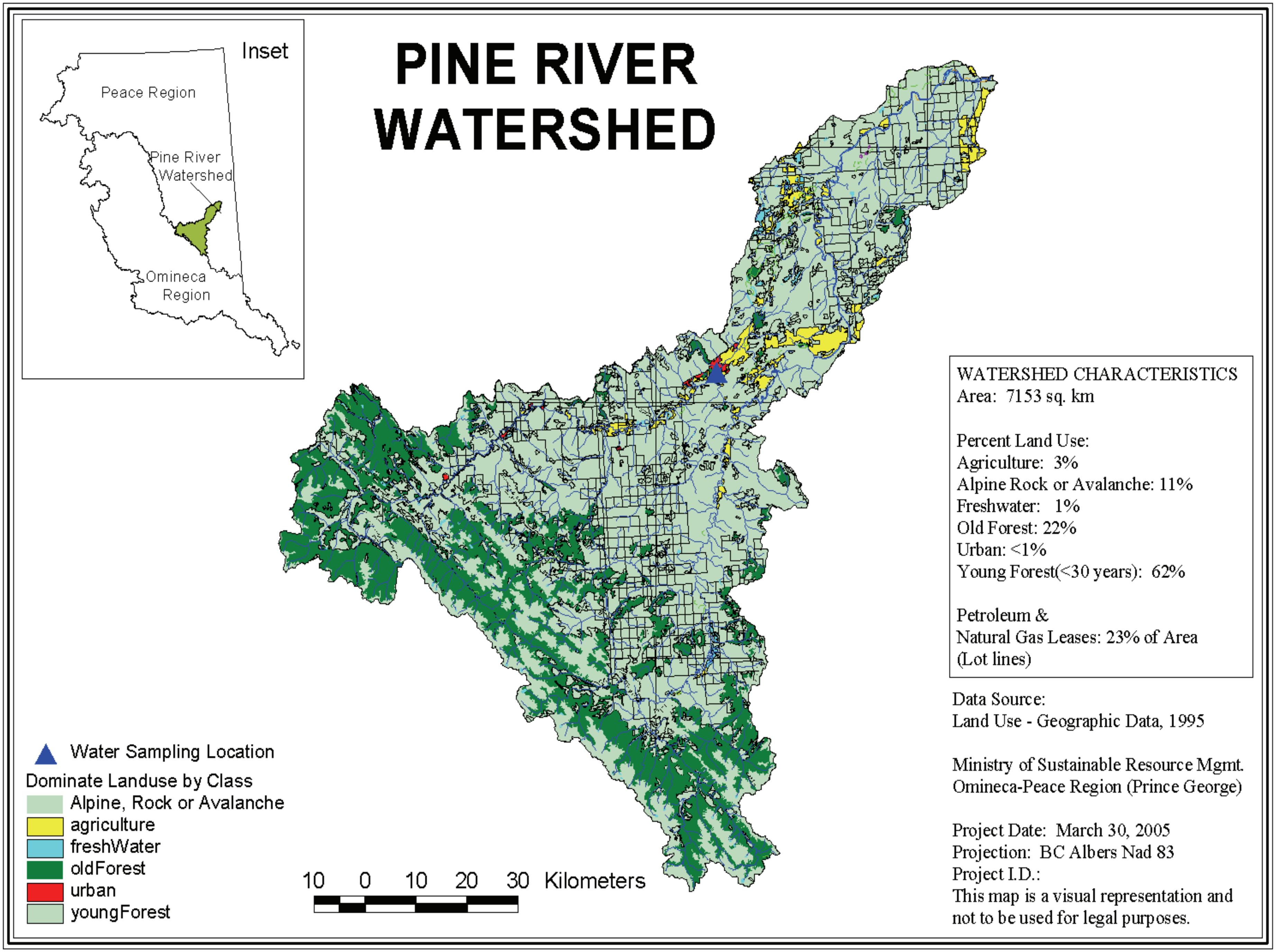

Figure 1. The Pine River watershed and associated land-use practices. It should be of note that the watershed statistics on this map are based on the entire watershed, not just the land-use activity upstream of the Chetwynd water intake.

Site Description

Watershed Overview

The Pine River watershed lies within four biogeoclimatic zones including the Boreal White and Black Spruce, Engelmann Spruce-Subalpine Fir, Sub-Boreal Spruce and Alpine Tundra (GOAT, 2003). The Boreal White and Black Spruce zone has long, extremely cold winters, with a short and cold summer growing season. The terrain has rolling topography, and is dominated by both upland forests and muskeg. Common trees in this zone include white spruce, black spruce, lodgepole pine and trembling aspen. The Engleman Spruce-Subalpine Fir zone has hilly, mountainous terrain, cold and snowy conditions (a snowpack of 2-3 m is common) for 5-7 months of the year, and short cool summers. The Sub-Boreal Spruce is characterized by gently rolling terrain, dense coniferous forests, and extremes in the annual temperature range of -40°C to 30°C. The Alpine Tundra zone is characterized by a rugged, treeless environment, amid tall cliffs and snow capped peaks. Much of the landscape is dominated by snow, ice and rock, with shallow bedrock and weathered soils covering much of the ground. This zone normally experiences abundant precipitation, and temperatures are usually cold for most of the year (the mean annual temperature range is 0°C to 4°C) (B.C. Ministry of Forests, 1998).

As measured at the Pine River Water Survey of Canada station 07FB001 (Pine River at East Pine), the Pine River drains approximately 12,100 km^2 and has a total length of 290 km. The general trend of the river is northeast, with some minor shifts in other directions. There are many tributaries to the Pine, with a complete list being available at fishwizard.com. The Pine River mainstem drains into the Peace River near Fort St. John (120° 42' 2.37"W; 56° 8' 27.78"N).

Many land use activities exist in the Pine drainage, including agriculture, range/grazing, forestry, oil & gas (including a pipeline that has approximately 17 river crossings (Massecar, p.c.)), mining and urban (Figure 1). Many of these activities are located upstream of the Chetwynd water intake, so drinking water contamination may be possible. New coal mine development upstream of the water intake includes Pine Valley Coal, which is located near Willow Creek.

Three major waste disposal permits exist with relevance to the Pine River around the District of Chetwynd. Two of these are downstream of the drinking water intake, so are not expected to be relevant in this study (the District's sewage effluent discharge and the District's water treatment plant discharge). The one upstream source is Aspen Mobile Estates, which discharges waste to the ground approximately 1.8 km from the Pine River (Van Nostrand, p.c.). Also, Pine Valley Coal discharges sediment pond water to the ground, but has been responsible for recent unplanned sediment discharges to Willow Creek, which enters the Pine River upstream of Chetwynd.

Nine water withdrawal licenses have been permitted on the Pine River, with the District of Chetwynd's waterworks being the most significant (1.20 x 10^6 m^3/yr). The total annual withdrawal from the licensed water users is approximately 1.30 x 10^6 m^3/yr. Based on information reported by Lands and Water B.C. and water discharge data supplied by Environment Canada, the total annual volume of water licensed to the various users is equivalent to approximately 0.02% of the annual flow at the Pine River flow station (55.718°N; 121.208°W).

Basic Hydrology

As indicated in the hydrograph below (Figure 2), flows in the Pine River are lowest during the winter months (November through March) and highest during late spring and early summer. There also appears to be a rise in the fall, most likely attributable to seasonal precipitation. Precipitation data provided by Environment Canada (measured at Chetwynd) follows similar trends to the hydrograph of the Pine River. Although we have not had the opportunity to undertake a detailed investigation of the hydrological factors that control flows in the Pine River, the hydrograph based on the most recent decade of data suggests a relatively normal flow pattern for a northern British Columbia river (Larsen, p.c.).

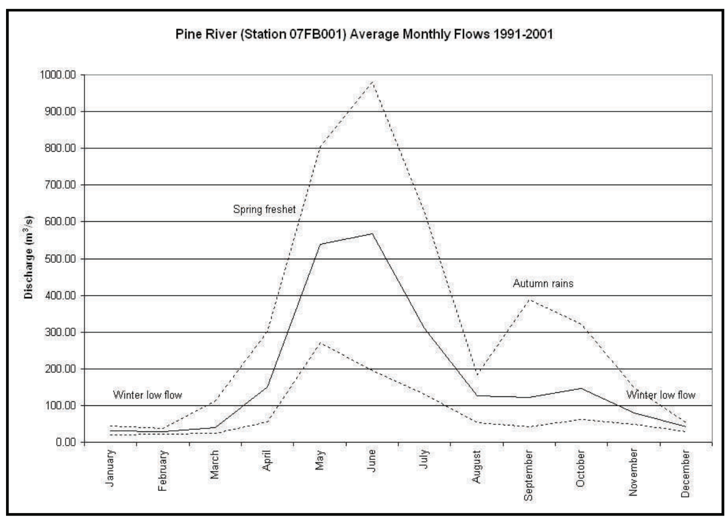

Figure 2. Lowest (bottom line), average (middle line) and maximum (upper line) monthly flows observed in the Pine River near Chetwynd over the period 1991-2001.

Drinking Water Supply & Treatment

The District of Chetwynd draws its domestic water from the Pine River, at geographic coordinates 55.6734° N/121.6468°W. From the lowlift station, the water is piped to a four million gallon storage pond and sequentially gravity fed to 11 million and 29 million gallon storage ponds (it is of note that the water can be piped directly from the lowlift station to either the 11 or 29 million gallon storage ponds). The water is then passed through a raw water strainer, injected with a coagulant, and passed through roughing (crushed granite) and finishing filters (coal, silica sand and gravel). The water is finished by sodium hypochlorite disinfection and then distributed throughout the community (Gosse, p.c.).

The District has ongoing concerns with all activities happening upstream of their water intake, and constantly monitor the river for any changes to its water quality. Furthermore, District staff visit upstream sites at least once a week to ensure no major problems are occurring (Gosse, p.c.). Examples of historical problems upstream of the Chetwynd water intake include cattle accessing the river and a large oil spill in 2000.

Materials & Methods

Review of Previous Data

Historical data relevant to the District of Chetwynd raw water supply assessment (Pine River) have been included in this report. Samples were collected by the B.C. Ministry of Environment between 1982 and 1992 at a site approximately 100m upstream of the municipal discharge (EMS site E206235). There is no known QA data associated with these samples.

Chemistry samples collected by the District of Chetwynd from the Pine River in 1995 have also been included.

Sample Collection & Analyses for the 2003-05 Water Monitoring Program

Water Quality

An experienced consultant and/or MOE staff member

Plate 2. A view of the parasite kit located on the left bank of the Pine River beside the lowlift pump station.

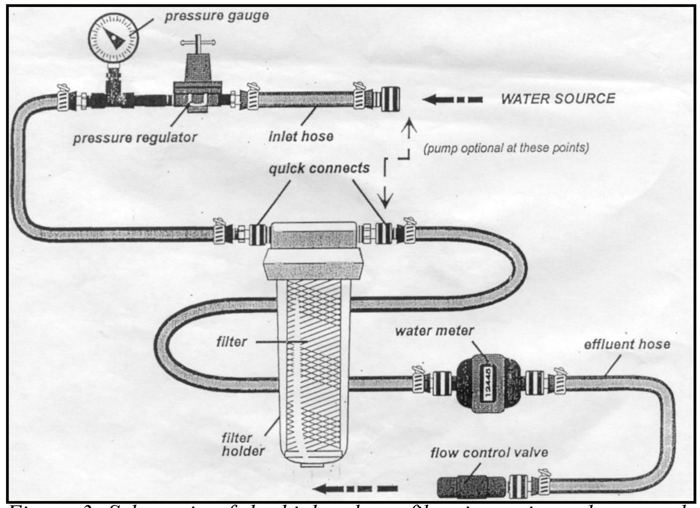

Figure 3. Schematic of the high-volume filtration unit used to sample raw water for Cryptosporidium oocysts and Giardia cysts (EPA, 1995).

collected water samples in laboratory certified polyethylene bottles for a variety of chemical and bacterial analyses. Representative grab samples were collected directly from the Pine River during most of the year when the raw water tap in the District pump house was not operational, and from the raw water tap during pumping periods (site E252349 - Water Source ID Tag 1348). The parameter results, analytical detection levels and drinking water quality guidelines are provided in Table A1, Appendix A. The full raw dataset is available on request.

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 JR Laboratories Inc. for bacteria and PSC Environmental Services Ltd. for chemistry. Bacterial samples were analysed using membrane filtration. Metals analysis made use of ICPMS technology. Dissolved metal samples were lab filtered within 24 hours after collection through a 0.45 µm membrane filter. Samples for the analysis of cysts and oocysts of the *Giardia* and *Cryptosporidium* parasites were collected using the high volume filtering method described in EPA (1995) (Plate 2 and Figure 3). Filters were shipped by overnight courier in a cooler with ice packs to the B.C. Centre for Disease Control's Enhanced Water Laboratory for analysis.

Quality Assessment

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 number.

Results

Review of Previous Data

Bacteriology

The Pine River was sampled by the B.C. Ministry of Environment 26 times between 1982 and 1992 for fecal coliforms at a site 100m upstream of the municipal sewage discharge. Fecal coliform densities ranged from less than detectable to 79 CFU. Densities were greater than recommended water quality guidelines (1 CFU/100mL) on 14 of the 26 dates. Refer to Table A2 in Appendix A.

Densities of fecal coliforms that exceed their recommended water quality guideline suggests that human illness may result should water treatment become ineffective.

Water Chemistry

Water chemistry results from the Ministry samples are presented in Table A2, Appendix A.

Most of the data did not show water quality concerns, however the turbidity levels did exceed their recommended drinking water guideline on some occasions. Most other parameter concentrations were consistent with those found during the 2003-05 program.

Water chemistry data was also provided by the District of Chetwynd, from Pine River samples collected one time in 1995 (Table A3, Appendix A). From this data, three parameters were of note. Turbidity, which was detected at 2.3 NTU, pH, detected at 5.07 and total hardness, detected at 184 mg/L. All three of these parameters have potential to affect aesthetic water quality, with the pH possibly promoting the dissolution of certain metals. However, the pH from this historical sample is much lower than current values indicate. Without any quality assurance associated with this data, the reliability of this below average concentration is low.

Water Monitoring Program (2003-05)

Quality Assessment

The field blank sample and duplicate results indicate that no field or lab contamination of samples with bacteria occurred and that acceptable precision in bacterial sampling and analysis was observed. The parasite analysis provided duplicate precision results for *Giardia* of between 7 and 26%. No duplicate *Cryptosporidium* oocyst analysis produced detectable results.

The five water chemistry field blank samples that were prepared either the same day or within one day of the Pine River collection 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. Four parameters exceeded these acceptance criteria and are listed in Table 1. These were excluded from our data analysis on these specific dates.

Table 1. Blind blank samples that tested strongly positive (≥ 5-fold MDL) for chemical contamination.

Date	Parameter	Measured Concentration	MDL
May 1/03	Nitrate + Nitrite	0.054 mg/L	0.002 mg/L
May 1/03	Sulphate	2.7 mg/L	0.5 mg/L
Dec. 1/04	Copper-T	0.53 µg/L	0.05 µg/L
Dec. 1/04	Copper-D	0.56 µg/L	0.05 µg/L

All of the blank exceedances were below the concentrations observed in the Pine River, and were usually 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 de-ionized water between bottles in the field. Regardless, these levels of blank contamination should not limit the comparison of other data to water quality guidelines.

The five water chemistry duplicate samples that were prepared either the same day or within one day of the Pine River did have some values outside the lab acceptance

Table 2. Duplicate samples that exceeded precision acceptability criteria (≤25% difference when > 5-fold MDL). All concentrations are in µg/L unless otherwise indicated.

Date/Parameter	MDL	Conc. 1	Conc. 2	RPD %
December 2003				
Aluminum-D	0.3	4.2	6.8	**47**
Colour	5	50	30	**50**
T.O.N. (mg/L)	0.1	0.69	1.36	**65**
Thallium-T	0.002	0.061	0.043	**35**
Thallium-D	0.002	0.049	0.025	**65**
September 2004				
Molybdenum-T	0.05	0.53	0.77	**37**
Phosphorus-T (mg/L)	0.002	0.045	0.025	**57**
December 2004				
Iron-T (mg/L)	0.005	0.067	0.099	**39**
Manganese-D	0.008	6.45	10.1	**44**

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

criteria of 25% relative percent difference (Table 2). The differences that are present may be due to problems with collection, analytical precision or natural variability. Most parameters that did have differences greater than 25% between duplicates existed at well below recommended drinking water guidelines. The only parameter to exceed its respective guideline was the colour sample collected in December, 2003. It is of note that this program duplicate sample was not collected from the Pine River.

Bacteriology

The 2003-05 bacterial data are summarised in Table 3. There are no water quality guidelines for raw drinking water receiving complete treatment, however the guideline for raw water receiving no treatment is 0 CFU/100mL for *E. coli*, *Enterococci* and fecal coliforms (should the current treatment system fail).

Bacterial counts were detected on most sampling dates during open water periods. The presence of fecal coliforms, *E. coli* and *Enterococci,* which all originate from the intestines of warm-blooded mammals, indicate the feces of wildlife, range animals, domestic animals and/or humans is present. As indicated on Figure 1, there are range activities located near the river upstream of the water intake. Furthermore, there are known incidents upstream of the water intake when livestock have been present in the main Pine River channel. This contamination indicates there is potential for bacterial-related human illness should water treatment become ineffective.

Table 3. Results of bacterial analyses for the District of Chetwynd's raw water supply. Units are CFU/100mL.

Date	Total Coliform	*E. coli*	*Enterococci*	Fecal Coliform
Provincial Guideline	No Provincial Guideline	*<1 CFU/100 mL (raw water)*	*<1 CFU/100 mL (raw water)*	*<1 CFU/100 mL (raw water)*
May 1/03	**12**	**4**	<2	**6**
May 29/03	**200**	<1	**23**	<1
Aug. 21/03	**28**	**15**	<1	32
Dec. 3/03	**10**	**3**	**2**	**3**
Mar. 24/04*	**1;2**	<1;<1	**2**;<1	<1;<1
May 25/04	**12;10**	**8;7**	<1;<1	**8;7**
Sep. 22/04*	**95;100**	**11;12**	**14;17**	**16;17**
Nov. 29/04*	-	**1**	<1	**1**
Feb. 22/05*	<1	<1	<1	<1

**Sample collected from raw water tap in pump house.*

Parasitology

The 2003-05 parasite data are summarised in Table 4. *Giardia* cysts were detected on all sample dates while *Cryptosporidium* oocysts were detected on three dates.

Data collected in 2003-05 indicates there is a problem with high *Giardia* cyst and detectable *Cryptosporidium* oocyst densities in the Pine River. Human illness resulting from these parasites is possible should water treatment become ineffective.

The B.C. Ministry of Health, as well as the U.S. Environmental Protection Agency (EPA, 1999), recommend a minimal removal or deactivation of 3 log (99.9%) for *Giardia* cysts through filtration and/or disinfection between raw and tap water. The EPA further suggests that it is important to consider multiple barriers of protection: watershed management, filtration, disinfection, and the protection of the integrity of the distribution system. The Chetwynd water treatment system currently uses sedimentation, filtration, coagulation and chlorination as means of treatment.

Table 4. Parasite densities observed in the District of Chetwynd's raw water supply over the period May 1st/2003 to February 22nd/2005.

Date	*Cryptosporidium* (oocysts/100L)	*Giardia* (cysts/100L)
May 1/03	**8.8**	**218.9**
Aug. 21/03	<3.9; <4.8	**146.6; 167.8**
Mar. 24/04	**6.3**	**100.9**
Sep. 22/04	<67.6	**337.8**
Nov. 29/04	**6.6**	**296.8**
Feb. 22/05	<2	**52**

**Detection level variations are due to changes in river turbidity. High turbidity levels interfere during the lab analysis process, and consequently can increase the level of detection.*

Water Chemistry

Water samples collected from the Pine River were analysed for 15 general chemistry parameters as well as for the ICPMS low level metals package that includes 27 metals in both the total and dissolved form.

Of the chemical parameters tested through the duration of this study, six were of interest (i.e. they either exceeded or were just below water quality guidelines at least once during the year). A description of these parameters, their concentrations during this study and possible anthropogenic sources are listed below (RIC, 1998).

Colour (TCU) - The maximum detected colour concentration was 50 TCU with a mean of 14.7 TCU and a median of 8.2 TCU (the recommended water quality guideline is 15 TCU). The colour of water is a measure of its dissolved compounds (attributed to the presence of organic and inorganic materials). High colour levels are regarded as a pollution problem in terms of aesthetics, and can be produced by agricultural and industrial effluents. Colour can also originate naturally from organic soils and wetlands.

Turbidity (NTU) - The maximum detected turbidity was 125 NTU, with a mean of 24.7 NTU and a median of 3.4 NTU (the recommended provincial DW guideline is 1 NTU and the aesthetic guideline is 5 NTU). Turbidity is a measure of the suspended particulate matter in the water, including silt, organic material and/or micro-organisms, that interfere with the passage of light. Turbidity can increase the available surface area of solids upon which bacteria grow, can interfere with disinfection and can be aesthetically unpleasant. High levels also decrease light penetration which can affect vegetation and algal growth. Some possible sources of increased turbidity are forest harvesting, road building, agriculture and urban development (RIC, 1998). Natural ground instabilities can also influence high turbidity levels.

Hardness, Total (mg/L $CaCO_3$) - The mean hardness of the raw water was 161 mg/L $CaCO_3$. Waters that exceed 120 mg/L $CaCO_3$ are considered hard. 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 sources that contribute to water hardness are mining and industrial effluents. Natural sources include a strong ground water input in areas with a concentration of dissolved calcium and magnesium.

Total Organic Carbon (mg/L) - The maximum TOC concentration was 7.9 mg/L, over the recommended guideline of 4 mg/L for a source water that uses disinfection. This is a measure of the dissolved and particulate organic carbon. TOC can be important in drinking water systems that use chlorination, as high levels can promote the formation of trihalomethanes which are considered carcinogens. Sources of TOC include agricultural, municipal and industrial waste discharges. Natural sources are similar to those for colour.

Iron, Total (mg/L) - The mean iron concentration was 1.16 mg/L with a median of 0.3 mg/L and a maximum of 5.97 mg/L, all equalling or exceeding the aesthetic guideline of 0.3 mg/L. Insoluble iron is often found in waters as colloidal material which can be difficult to remove. Additionally, iron has the tendency to colour water. Iron is found naturally in many water supplies, however, anthropogenic sources include industrial effluents (burning of coal), acid mine drainage and smelters.

Manganese, Total (μg/L) - The mean manganese concentration was 30.3 μg/L with a maximum of 135 μg/L. The aesthetic objective is 50 μg/L. Similar to iron, manganese can colour water and form colloidal material that can be difficult to remove. Manganese is found naturally in many water supplies originating from the weathering of rocks and minerals, with anthropogenic sources including industrial effluents, fertilizers, gasoline (Manganese is an additive), as well as many other sources.

The remaining parameters generally had low concentrations and are below recommended water quality guidelines. For a complete list of the parameters and their associated concentrations, refer to Table A1 in Appendix A.

Conclusions & Recommendations

Review of the Pine River data indicates a raw water quality unsuitable for human consumption without treatment. *Giardia, Cryptosporidium,* as well as fecal bacteria were detected at concentrations above recommended levels, suggesting that warm-blooded animals or runoff from animal waste is accessing the Pine or tributaries upstream of the water intake. Although wildlife may be the source of some of these organisms, range activities do exist in the watershed, as indicated on Figure 1. An ongoing bacterial/parasite program should continue, so as to identify any trends in the data, as well as to help the District identify times of the year when the water quality is poor. Furthermore, testing for parasites in treated water may be useful to ensure the current treatment system is effective in removing harmful cysts and oocysts. Additionally, as per the EPA recommendation on high parasite densities, a watershed management program may be useful in the Pine River basin. It is of note that testing for bacteria and parasites is done independently, as no relationship is found between parasite cyst/oocyst levels and bacterial indicators of water contamination (EPA, 1999).

As mentioned in the hydrology section of this report, the Pine River appears to be responsive to large scale precipitation events. It is recommended that particular care be taken by the District with respect to the intake of bacterial levels after these large storm events, which can increase in the river via overland flow contributions.

Many of the chemical parameters detected over recommended water quality guidelines naturally occur in many northern streams and ground water supplies. However, careless land-use practices can affect the concentration of these parameters, to further degrade water quality.

Since 2004, the mining activity in the Pine River watershed has increased. Care should be taken at these mines not to substantially alter the water quality of upstream tributaries, which may alter the source water quality at the Chetwynd water intake. Regular monitoring of mining induced parameters upstream of the water intake is part of a normal operation.

Acknowledgements

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Contact Information

For more information regarding either this short report, watershed protection and/or drinking water, please contact the Ministry of Environment Protection (Contact: James Jacklin , 250-565-4403 or Dave Sutherland (Prince George), 250-565-6465) or the Northern Health Authority (Contact: Bruce Gaunt (Prince George), 250-565-2150 or Caroline Alexander (Fort St. John), 250-787-3355).

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Appendix A

Water Quality Tables

Table A1. 2003-05 sample parameters, summaries of current results and associated B.C. drinking water guidelines.

Parameter	*n*	Min.	Max.	Mean	Median	Std. Dev.	MDL	Guideline	Guideline Type
Parasites									
Cryptosporidium	6	4.4	8.8	6.5	6.5	1.8			
Giardia	6	52.0	337.8	193.9	188.1	111.4			
Bacteria									
Total Coliforms	8	1	200	45.1	11.5	70.1			
Fecal Coliforms	9	1	32	7.7	3.0	10.4		< 1	raw water-no treatment
Enterococci	9	1	23	5.3	1.5	8.1		< 1	raw water-no treatment
E. Coli	9	1	15	5.0	3.0	5.2		< 1	raw water-no treatment
General									
pH	9	8	8.3	8.15	8.15	0.087	0.1	6.5-8.5	aesthetic objective
Colour (TCU)	9	5	50	14.7	8.2	15.93	5	≤ 15	aesthetic objective
Specific Conductance (µS/cm)	9	175	371.5	284.5	294	61.97	1	≤ 700	maximum acceptable concentration
Turbidity (NTU)	9	0.8	125	24.8	3.4	40.27	0.1	≤ 1	maximum acceptable concentration
Hardness Total (mg/L)	9	116.5	196	161.5	171.0	29.37			maximum acceptable concentration
Hardness Total -Diss. (mg/L)	9	94.3	197	153.2	165.5	36.72		≤ 500 $CaCO_3$	aesthetic objective
Alkalinity (mg/L)	9	91.1	161	134.7	151.0	25.91	0.5		
Residue Non-Filterable (mg/L)	9	4	254	48.1	6.0	82.52	4		
Total Organic Carbon (mg/L)									
TOC	9	0.6	7.9	3.2	3.3	2.16	0.5	≤ 4	maximum, to control THM production
Anions (mg/L)									
Chloride Dissolved	9	0.5	3.2	1.9	2.3	0.85	0.5	≤ 250	aesthetic objective
Fluoride Dissolved	9	0.03	0.09	0.064	0.1	0.018	0.01		
Bromide Dissolved	9	0.1	0.1	0.10	0.1	0.000	0.1		
Nutrients (mg/L)									
Nitrate+Nitrite	8	0.013	0.092	0.055	0.1	0.028	0.002	≤ 45 (NO_3)	maximum acceptable concentration
Phosphorus Total	9	0.002	0.183	0.042	0.0	0.063	0.002	≤ 1.5	maximum acceptable concentration
Phosphorus Total-Diss.	9	0.002	0.02	0.005	0.0	0.006	0.002		
Sulphate (mg/L)									
Sulphate	8	6.9	30.4	17.6	17.6	7.38	0.5	≤ 500	aesthetic objective
Metals Total (µg/L)									
Aluminum-T	9	22.9	452	112.9	71.0	140.226	0.3		
Aluminum-D	9	0.9	31.7	10.6	3.7	12.21	0.3	≤ 200	maximum acceptable concentration
Antimony-T	9	0.074	0.168	0.099	0.1	0.028	0.005	≤ 6	interim maximum acceptable concentration
Antimony-D	9	0.068	0.114	0.084	0.1	0.015	0.005		
Arsenic-T	9	0.1	0.9	0.3	0.2	0.25	0.1	≤ 25	interim maximum acceptable concentration
Arsenic-D	9	0.1	0.3	0.2	0.2	0.07	0.1		
Barium-T	9	78.35	133	110.55	111.0	16.558	0.02	≤ 1000	maximum acceptable concentration
Barium-D	9	61.8	117	95.4	102.0	19.28	0.02		
Beryllium-T	9	0.02	0.1	0.03	0.0	0.026	0.02		
Beryllium-D	9	0.02	0.02	0.02	0.0	0.000	0.02		
Bismuth-T	9	0.02	0.1	0.03	0.0	0.026	0.02		
Bismuth-D	9	0.02	0.07	0.03	0.0	0.017	0.02		
Cadmium-T	9	0.01	0.43	0.08	0.0	0.133	0.01	≤ 5	maximum acceptable concentration
Cadmium-D	9	0.01	0.025	0.017	0.0	0.006	0.01		
Calcium-T (mg/L)	9	35.05	57.85	47.89	50.8	8.697	0.05		
Calcium-D (mg/L)	9	28.5	58.05	46.73	51.7	10.791	0.05		
Chromium-T	9	0.2	1.7	0.39	0.2	0.494	0.2	≤ 50	maximum acceptable concentration
Chromium-D	9	0.11	0.7	0.25	0.2	0.173	0.2		
Cobalt-T	9	0.005	1.8	0.321	0.1	0.572	0.005		
Cobalt-D	9	0.005	0.103	0.046	0.0	0.035	0.005		

Table 1 Continued.

Parameter	*n*	Min.	Max.	Mean	Median	Std. Dev.	MDL	Guideline	Guideline Type
Copper-T	8	0.26	4.39	1.19	0.9	1.359	0.05	≤ 1000	aesthetic objective
Copper-D	8	0.22	1.065	0.547	0.6	0.274	0.05		
Iron-T (mg/L)	9	0.045	5.97	1.157	0.3	2.019	0.005	≤ 0.3	aesthetic objective
Iron-D (mg/L)	9	0.005	0.110	0.035	0.0	0.036	0.005		
Lead-T	9	0.03	3.26	0.62	0.2	1.027	0.01	≤ 10	maximum acceptable concentration
Lead-D	9	0.01	0.1	0.03	0.0	0.030	0.01		
Lithium-T	9	4.77	14.3	10.55	12.1	3.511	0.05		
Lithium-D	9	3.95	14.2	9.80	11.0	3.516	0.05		
Magnesium-T (mg/L)	9	7.055	12.5	10.177	10.8	1.862	0.05		
Magnesium-D (mg/L)	9	5.61	12.6	9.79	10.4	2.280	0.05	≤ 100	aesthetic objective
Manganese-T	9	7.36	135	30.31	18.4	40.538	0.008	≤ 50	aesthetic objective
Manganese-D	9	2.1	25.4	8.8	6.8	7.26	0.008		
Molybdenum-T	9	0.46	1.45	0.98	1.0	0.291	0.05	≤ 250	maximum acceptable concentration
Molybdenum-D	9	0.46	1.55	0.92	0.9	0.322	0.05		
Nickel-T	9	0.05	4.66	1.12	0.7	1.393	0.05		
Nickel-D	9	0.05	0.965	0.44	0.5	0.284	0.05		
Selenium-T	9	0.2	0.65	0.45	0.5	0.132	0.2	≤ 10	maximum acceptable concentration
Selenium-D	9	0.2	0.8	0.4	0.4	0.18	0.2		
Silver-T	9	0.02	0.02	0.02	0.0	0.000	0.02		
Silver-D	9	0.02	0.02	0.02	0.0	0.000	0.02		
Sodium-T (mg/L)	9	1.34	3.97	2.91	3.3	1.004	0.05	≤ 200	aesthetic objective
Strontium-T	9	124	315	228	245	73.9	0.005		
Strontium-D	9	105	317	217	229	75.8	0.005		
Thallium-T	9	0.003	0.036	0.011	0.0	0.010	0.002	≤ 2	maximum acceptable concentration
Thallium-D	9	0.002	0.009	0.005	0.0	0.002	0.002		
Tin-T	9	0.01	0.06	0.02	0.0	0.017	0.01		
Tin-D	9	0.01	0.02	0.01	0.0	0.004	0.01		
Uranium-T	9	0.258	0.46	0.393	0.4	0.072	0.002	≤ 100	maximum acceptable concentration
Uranium-D	9	0.213	0.448	0.347	0.4	0.085	0.002		
Vanadium-T	9	0.28	4.01	1.20	0.6	1.354	0.06	≤ 100	maximum acceptable concentration
Vanadium-D	9	0.06	2.1	0.54	0.3	0.649	0.06		
Zinc-T	9	0.1	15.4	4.1	2.9	4.71	0.1	≤ 5000	aesthetic objective
Zinc-D	9	0.1	5.4	1.2	0.6	1.66	0.1		

Table A2. Historical water quality data collected 100m upstream of the District of Chetwynd municipal discharge. Data were collected from 1982-1992.

Parameter	*n*	Range	Mean	Median
Ammonia Dissolved (mg/L)	26	<0.005-0.009	0.0051	0.005
Chloride (mg/L)	13	0.8-2.6	1.72	1.8
Fecal Coliforms (CFU/100mL)	25	<2-79	7.64	2
TOC (mg/L)	2	1-4	2.5	2.5
Nitrate + Nitrite (mg/L)	29	<0.005-0.073	0.027	0.02
Ortho-P (mg/L)	29	<0.001-0.003	0.0025	0.003
Total Phosphorus (mg/L)	11	0.003-0.116	0.034	0.016
Total Diss. Phos. (mg/L)	25	<0.003-0.007	0.004	0.003
Residue, Non-Filterable (mg/L)	18	1-148	20.3	4
Specific Conductance (µS/cm)	28	157-400	297	312
Turbidity (NTU)	12	1-32	5.6	3
pH (pH units)	25	8-8.4	8.2	8.2

Table A3. Historical Chemistry Data collected from the Pine River by the District of Chetwynd, 1995.

Parameter	Unit	Pine River	Parameter	Unit	Pine River
pH	pH Units	5.07	Cadmium	mg/L	<0.0005
Colour	Col. Unit	<5	Cobalt	mg/L	<0.003
Sp. Conductivity	µS/cm	421	Chromium	mg/L	<0.004
Turbidity	NTU	2.3	Copper	mg/L	<0.005
Hardness Total	mg/L	184	Iron	mg/L	0.21
Alkalinity Total	mg/L	173	Potassium	mg/L	<0.9
Chloride Dissolved	mg/L	2.8	Magnesium	mg/L	12.1
Fluoride Dissolved	mg/L	0.3	Mercury	mg/L	<0.0000
Nitrogen NO_3 Diss	mg/L	0.084	Molybdenum	mg/L	0.011
Nitrogen NO_2 Diss	mg/L	<0.003	Sodium	mg/L	4.32
Sulphate	mg/L	40	Nickel	mg/L	<0.01
Silver	mg/L	<0.01	Lead	mg/L	<0.001
Aluminum	mg/L	<0.05	Antimony	mg/L	0.04
Arsenic	mg/L	<0.001	Selenium	mg/L	<0.005
Boron	mg/L	<0.01	Silicon	mg/L	2.24
Barium	mg/L	<0.08	Tin	mg/L	<0.06
Beryllium	mg/L	<0.001	Titanium	mg/L	<0.04
Bismuth	mg/L	<0.06	Vanadium	mg/L	<0.03
Calcium	mg/L	55.7	Zinc	mg/L	0.004

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