Canada Alberta Northwest Territories

Northern River Basins Study





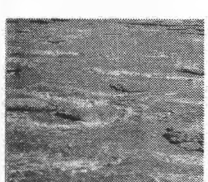




NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 116

AN ASSESSMENT OF NON-CONVENTIONAL DRINKING WATER

IN THE PEACE, ATHABASCA AND SLAVE RIVER BASINS






DATE DUE

Prepared for the
Northern River Basins Study
under Project 4423-D1

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Published by the
Northern River Basins Study
Edmonton, Alberta
March, 1997

CANADIAN CATALOGUING IN PUBLICATION DATA

Armstrong, T. F.

An assessment of non-conventional drinking water
in the Peace, Athabasca and Slave River Basins

(Northern River Basins Study project report,
ISSN 1192-3571 ; no. 116)
Includes bibliographical references.
ISBN 0-662-24655-1
Cat. no. R71-49/3-116E

1. Drinking water -- Alberta -- Athabasca River Watershed.
2. Drinking water -- Peace River Watershed (B.C. and Alta.)
3. Drinking water -- Slave River Watershed (Alta. and N.W.T.)

I. Stanley, Stephen J. (Stephen John), 1962-
II. Smith, D. W. (Daniel Walter), 1944-
III. Northern River Basins Study (Canada)
IV. Title.
V. Series.

TD226.A75 1997 553.7'097123'1 C96-980231-5

PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the Study Area by coordinating with existing programs and undertaking appropriate new technical studies.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

NORTHERN RIVER BASINS STUDY
PROJECT REPORT RELEASE FORM

This publication may be cited as:

Armstrong, T. F., Stanley, S. J. and Smith, D. W. 1997. ***Northern River Basins Study Project Report No. 116, An Assessment of Non-conventional Drinking Water in the Peace, Athabasca and Slave River Basins.*** **Northern River Basins Study, Edmonton, Alberta.**

Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,
IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
this publication be subjected to proper and responsible review and be considered for release to the public.

F J Wrona — 14 May 96

(Dr. Fred J. Wrona, Science Director) — (Date)

Whereas it is an explicit term of reference of the Science Advisory Committee "to review, for scientific content, material for publication by the Board",
IT IS HERE ADVISED BY THE SCIENCE ADVISORY COMMITTEE THAT;
this publication has been reviewed for scientific content and that the scientific practices represented in the report are acceptable given the specific purposes of the project and subject to the field conditions encountered.
SUPPLEMENTAL COMMENTARY HAS BEEN ADDED TO THIS PUBLICATION: [ ] Yes [ ] No

P A Larkin — 24 May / 96

(Dr. P. A. Larkin, Ph.D., Chair) — (Date)

Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,
IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public, and that this publication be designated for: **[ ] STANDARD AVAILABILITY [ ] EXPANDED AVAILABILITY**

Lucille Partington — May 29/96

(Lucille Partington, Co-chair) — (Date)

Robert McLeod. — May 21/96

(Robert McLeod, Co-chair) — (Date)

AN ASSESSMENT OF NON-CONVENTIONAL DRINKING WATER IN THE NORTHERN RIVER BASINS

STUDY PERSPECTIVE

Water is essential to life and it can be an important vector for conveying contaminants into humans. To assist the Northern River Basins Study (NRBS) Board in making recommendations about the safety of drinking water supplies, the Drinking Water component designed a five-step program of studies. The steps included:

1. synthesis of existing data on water use and water quality;
2. investigation of odour in water and tainting in fish;
3. review of health records for water borne diseases;
4. assessment of conventionally treated and non-conventional water; and
5. preparation of a synthesis report.

> ***Related Study Questions***
>
> *2) What is the current state of water quality in the Peace, Athabasca and Slave River basins, including the Peace-Athabasca Delta?*
>
> *8) Recognizing that people drink water and eat fish from these river systems, what is the current concentration of contaminants in water and edible fish tissue and how are these levels changing through time and by location?*

This project report addresses the non-conventional component of step four. Non-conventional sources of drinking water refers to drinking water not received directly from conventional water treatment facilities. These sources include: self-hauled treated water, surface water, dugouts; ground water; snow, rain and birch tree water; bottled water and water treated by a variety of point-of-use technologies. From other NRBS work it is estimated that 25% of the residents of the Study area do not receive their water from conventional drinking water treatment facilities.

The non-conventional assessment had four parts that included: 1) a literature review of non-conventional drinking water sources, drinking water quality and a correlation of drinking water with human health, 2) interviews with residents concerning their use of non-conventional drinking water, 3) laboratory analysis of non-conventional drinking water samples and an assessment of compliance with the Guidelines for Canadian Drinking Water Quality (GCDWQ) and 4) laboratory testing of three point-of-use water filters.

Important project findings include: there is little information available on the use and quality of non-conventional drinking water, bacterial contamination is common, further assessment is required before any of the portable drinking water treatment filters could be condoned as a viable treatment option, and their is limited understanding of traditional uses and the cultural significance attached to drinking water obtained from natural sources. It was concluded that the consumption of untreated surface water is not recommended. Boiling water of unknown quality for at least one minute remains the most available means for minimizing microbial contamination. This treatment will inactivate most pathogens but will not affect the physical and chemical properties of the water. The best technology for water purification is a function of the raw water quality and it is likely that multiple processes will be required to treat it satisfactorily.

Information from this report will be combined with information collected in "Independent Assessment of Drinking Water Quality in the Northern River Basins" (NRBS Report Number 115) to give an overview of drinking water quality in the Northern River Basins. Together with the other Drinking Water projects, these studies will form the basis for the Drinking Water Synthesis report (NRBS Synthesis Report Number 9). Information from this project is also being made available to the Human Health Monitoring Program that is examining health issues in Northern Alberta.

REPORT SUMMARY

It is estimated that approximately 25 % of the residents of the Northern River Basins Study area do not receive their drinking water from conventional drinking water treatment facilities. Therefore, these people rely on alternative sources for their drinking water supply. This report assesses the utilization and quality of the different *non-conventional* sources of drinking water that are used by people that do not consume conventionally treated water. Some of the non-conventional drinking water supplies utilized in the NRBS area include: (1) self-hauled treated water; (2) untreated surface water; (3) dugout water; (4) groundwater; (5) environmental sources of water such as snow, rain, and birch tree water; (6) bottled water; and (7) water treated by a variety of point-of-use technologies. There were four main research components in the assessment of these non-conventional drinking water supplies.

First, the results of an in-depth review of the literature available on non-conventional drinking water sources, drinking water quality and the correlation of drinking water and health is presented in the first part of this report. Although the literature was limited on the actual consumption and quality of most of the non-conventional sources of drinking water consumed in the study area, substantial information exists on conventional drinking water quality as well as considerable information on several point-of-use treatment technologies. Essentially, the best type of point-of-use treatment depends on the raw water source. Perhaps the best point-of-use treatment method to use on water of unknown quality is to boil it. The recommended boiling time in the literature varies considerably from simply heating the water to 50°C to vigorous boiling for 15 minutes. However, the majority of the authors cited a full boil for 1 minute as being sufficient to inactivate most pathogens. Besides boiling, there are numerous other point-of-use treatment technologies that employ disinfection (ultraviolet disinfection, ozonation, chlorination, iodination) and mechanical particle removal processes (such as sedimentation and filtration). The best available technology depends on the raw water source and likely incorporates more than one process to provide multiple barriers to ensure adequate drinking water quality.

The second component of research regarding non-conventional drinking water in the Northern River Basins Study are was to visit selected NRBS communities and interview residents regarding their non-conventional drinking water practices. Remote areas around Fort Chipewyan, John D'Or Prairie, Fox Lake and Atikameg were visited and residents were asked about the sources and utilization on non-conventional drinking water supplies, as well as their overall drinking water quality concerns. It was through these informal interviews that most of the information was collected on the types of non-conventional drinking water used and how it was treated, if at all, prior to consumption. Many of the people interviewed discussed the deterioration of some of the surface water sources in the study area, but the majority of the concerns presented regarding drinking water quality in this study was in regards to the addition of chlorine in the conventional drinking water treatment process. Based on this, it was found that some people who do have conventionally treated water delivered to their home, collect a non-conventional supply of water for consumption such as from a nearby lake or river. This water has been called "special drinking water" by those consumers. It was also based on these findings that a series of population sub-groups that may be particularly pre-disposed to consuming non-conventional drinking water was postulated. First, those that live in remote areas not

serviced by conventional drinking water facilities are obvious consumers of non-conventional drinking water supplies. Second, some NRBS residents may be traditional consumers of alternative drinking water supplies. Many elderly residents may be included in this second group. Third, NRBS residents may consume non-conventional drinking water as a result of cultural activities such as living off the land expeditions or other wilderness activities. And the final group includes those individuals that consume non-conventional drinking water supplies for health reasons. This may include people that drink bottled water for its perceived health benefits as well as those that consume *special drinking water* to avoid the taste and smell of chlorine in conventionally treated water.

Third, during these field trips, samples of non-conventional drinking water were collected and these samples were analyzed for various physical, chemical and microbiological parameters. The non-conventional samples collected included untreated lake, river and creek water, spring water, groundwater well water, snow water, bottled water, and one sample of water treated with a point-of-use filter. Although the number of samples collected was limited and does not allow for absolute conclusions, several trends can be hypothesized. It was found that untreated surface water did not meet many of the physical, chemical and microbial guidelines in the GCDWQ. Although the groundwater samples collected met the microbiological limits in the GCDWQ, some physical and chemical parameters may be exceeded. The bottled water samples were found to have a very high background bacterial count and the point of use device tested was found to have actually contributed coliforms to the influent water supply.

The fourth component in the assessment of non-conventional drinking water supplies in the Northern River Basins Study area was to pursue research on the effectiveness on some of the portable point-of-use drinking water treatment filters on the market. The reason for this was because there is a very limited body of literature regarding these devices, and the claims made by the manufacturers suggest that these units are suitable to provide a safe supply of drinking water for wilderness campers and travelers. For the rigorous laboratory testing of these units, three filters were chosen to represent the larger market. The filters were chosen based on the type of filter media (carbon media, plastic media and silver impregnated ceramic media were selected), the price range (least expensive to most expensive were tested), and each unit was from a different manufacturer. The filters were subjected to an influent test water with a high turbidity, high bacterial count and a high particle count. It was found that only the silver impregnated ceramic filter was capable of reducing the turbidity, bacterial count and particle levels to below recommended levels for supplying a safe drinking water. However, further microbiological tests on this unit are required before it can be recommended for utilization in the study area.

ACKNOWLEDGEMENTS

There are countless people who contributed to the results of this study. During the course of this research, there were many individuals working at the university and in government departments that were called upon for their information and advice. Although it is not possible to name all the people consulted, we would like to extend our sincere thanks to them.

The maps included in this report are a result of the expertise of Erik Ellehoj from the NRBS study office, and David Gibbons from PFRA. The authors appreciate the efforts of these two individuals and would like to thank them for their illustrative abilities.

Without the assistance and guidance of the community members that acted as sampling guides during the field trips, many of the findings of this research project would have been unattainable. Researchers are indebted to the following community guides for their knowledge regarding non-conventional sources of drinking water and for their recommendations on good sampling locations:

Art Bingham	High Level, Alberta
Rosie Chalifoux	Atikameg, Alberta
Fred (Jumbo) Fraser	Fort Chipewyan, Alberta
Lesley Laboucan	Fox Lake, Alberta
Lester St. Arnault	John D'Or Prairie, Alberta

There were many other community people who were involved in the gathering of information on non-conventional drinking water practices in the Northern River Basins. We would specifically like to thank the following people for inviting us into their homes and sharing their ideas and experiences regarding drinking water with us:

John and Lena Courtoreille	Prairie River near Fort Chipewyan, Alberta
Stanley and Susan Laboucan	Fox Lake, Alberta
Raymond, Yvonne and Jonah Ladouceur	Fort Chipewyan, Alberta
Stella Marten	Fort Chipewyan, Alberta
Andrew Sewepagaham	John D'Or Prairie, Alberta
Lester St. Arnault	John D'Or Prairie, Alberta

In addition, there were other community members that also deserve mention for their contributions to the findings of this report:

David Campbell	Fort Chipewyan, Alberta
Kirk Campbell	Fort Chipewyan, Alberta
Willie Courtoreille	Fort Chipewyan, Alberta
Sarah DeCoutere	Fort Chipewyan, Alberta
Scott Flett	Fort Chipewyan, Alberta
Sonny Flett	Fort Chipewyan, Alberta
Audrey Graham	Fox Lake, Alberta

Dwayne Laboucan	Fox Lake, Alberta
George Marten	Fort Chipewyan, Alberta
Sammy Marten	Fort Chipewyan, Alberta
Terry Marten	Fort Chipewyan, Alberta
Louis Marten	Quatre Forches near Fort Chipewyan, Alberta
Bev Meikel	John D'Or Prairie, Alberta
Elaine Schleifer	Atikameg, Alberta
Wendy Warden	Fort Vermilion, Alberta

And finally, we would like to thank the aboriginal leaders in the NRBS area for allowing us to learn more about non-conventional sources of drinking water used in their communities. We would specifically like to thank Lea Bill for her *traditional knowledge* regarding this study and in particular for sharing some of her culture with us. This helped to put this research project into perspective. *Nanaskimwun.*

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LIST OF ABBREVIATIONS

AEP	Alberta Environmental Protection
AO	Aesthetic objective
As	Arsenic
AWWA	American Water Works Association
B	Boron
Ba	Barium
Cd	Cadmium
cfu	Colony forming unit
Cr	Chromium
Cu	Copper
FC	Fecal coliforms
Fe	Iron
FS	Fecal streptococci
Hg	Mercury
HPC	Heterotrophic plate count
IARC	International Agency for Research on Cancer
IMAC	Interim maximum acceptable concentration
MAC	Maximum acceptable concentration
Mn	Manganese
NRBS	Northern River Basins Study
NRC	National Research Council
NTU	Nephelometric turbidity units
Pb	Lead
PFRA	Prairie Farm Rehabilitation Administration
POU	Point-of-use
TC	Total coliforms
TDS	Total dissolved solids
THM	Trihalomethane
THM-FP	Trihalomethane formation potential
TOC	Total organic carbon
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
Zn	Zinc

1. INTRODUCTION

1.1 NORTHERN RIVER BASINS STUDY

The Northern River Basins Study (NRBS) is a four and a half year study that is aimed at examining the relationship between development and the Peace, Athabasca and Slave river basins. This study is somewhat unique because of its multi-stakeholder approach which encourages the input and participation of the public. Eight scientific components have been set up to answer a series of guiding questions that are central to the Northern River Basins Study. These components are (1) Traditional Knowledge; (2) Other Uses; (3) Drinking Water; (4) Hydrology/Hydraulics/Sediment; (5) Food Chain; (6) Contaminants; (7) Nutrients; and (8) Synthesis and Modelling. The assessment of non-conventional drinking water in the NRBS area is within the scope of the Drinking Water Component.

1.2 DRINKING WATER COMPONENT

The primary guiding question that the Drinking Water Component is set up to answer is:

> "Recognizing that people drink water and eat fish from these river systems, what is the current concentration of contaminants in water and edible fish tissue and how are these levels changing through time and by location? (Northern River Basins Study, 1994)"

The Drinking Water Component has devised a number of linked studies to try to answer this guiding question. The quality of the drinking water has been assessed in several ways. Initially, the aesthetic quality of the water was studied in the form of taste and odour analyses on the Peace and Athabasca Rivers. In addition, a historical analysis of existing water quality data was synthesized from Alberta Environment databases. This was followed by site visits to water treatment plants in 38 communities in the NRBS area in which samples were analyzed and operators were interviewed. But, a large percentage of residents in the study area do not receive their drinking water from conventional treatment plants such as these. Therefore, an assessment of the non-conventional sources of drinking water and the treatment utilized was also addressed by the Drinking Water Component. This is the topic of this report.

1.3 NON-CONVENTIONAL DRINKING WATER ASSESSMENT

As of September 1994, there were approximately 228 300 people living in the Northern River Basins Study area (Prince et al., 1995). It is estimated that 25% of these people do not receive their drinking water from conventional water treatment plants. In order to obtain safe potable water, people living in areas where conventionally treated water is unavailable must provide some other form of treatment. Therefore, it is important to assess the utilization of alternative drinking water sources in the NRBS area, as well as the effectiveness of the non-conventional methods used to treat the water.

To accomplish this, a review of the literature pertaining to drinking water quality, health effects of drinking water contaminants and methods of conventional and non-conventional drinking water treatment methods was completed. Following this, researchers from the Drinking Water Component visited areas suggested by Traditional Knowledge Component leaders as potential places where people live in remote areas not serviced by conventional treatment plants (Flett and Bill, 1994). The areas chosen for site visits included isolated areas around Fort Chipewyan and remote locations near John D'Or Prairie, Fox Lake and Atikameg. During these field trips, local residents were interviewed regarding their drinking water treatment practices, particularly when they were living off of the land, and samples of water were taken from locations suggested by local people as sources of non-conventional drinking water. These samples were analyzed for various physical, chemical and microbiological parameters.

During these field trips it was realized that many people in the NRBS area may spend weeks at a time living off of the land without access to conventionally treated water. Currently, there are portable water treatment filters on the market that claim to be suitable for expeditions such as these. Therefore, as part of this study, three different types of portable point-of-use devices were tested in the lab and assessed for their effectiveness and suitability for use in remote areas in the Northern River Basins.

2. STUDY AREA

The boundaries of the Northern River Basins Study include all areas that drain into the Peace River, Athabasca River and the Slave River. This includes a large proportion of Northern Alberta and parts of British Columbia, Saskatchewan and the North West Territories. As Figure 1 shows, three areas were chosen as places to assess the utilization of non-conventional sources of drinking water and to take samples of water from which drinking water is obtained. The first of these was in the Fort Chipewyan area which is the central meeting place of all three river basins. Research in this area was conducted from September 26, 1994 to September 29, 1994. Secondly, from October 31, 1994 to November 4, 1994 communities near High Level, John D'Or Prairie and Fox Lake were visited, people were interviewed and samples were taken. On February 28, 1995, water samples were collected from Atikameg which is located north of Lesser Slave Lake in the Peace River Basin. The economy of this region relies on a variety of livelihoods, including agriculture, forestry and mining.

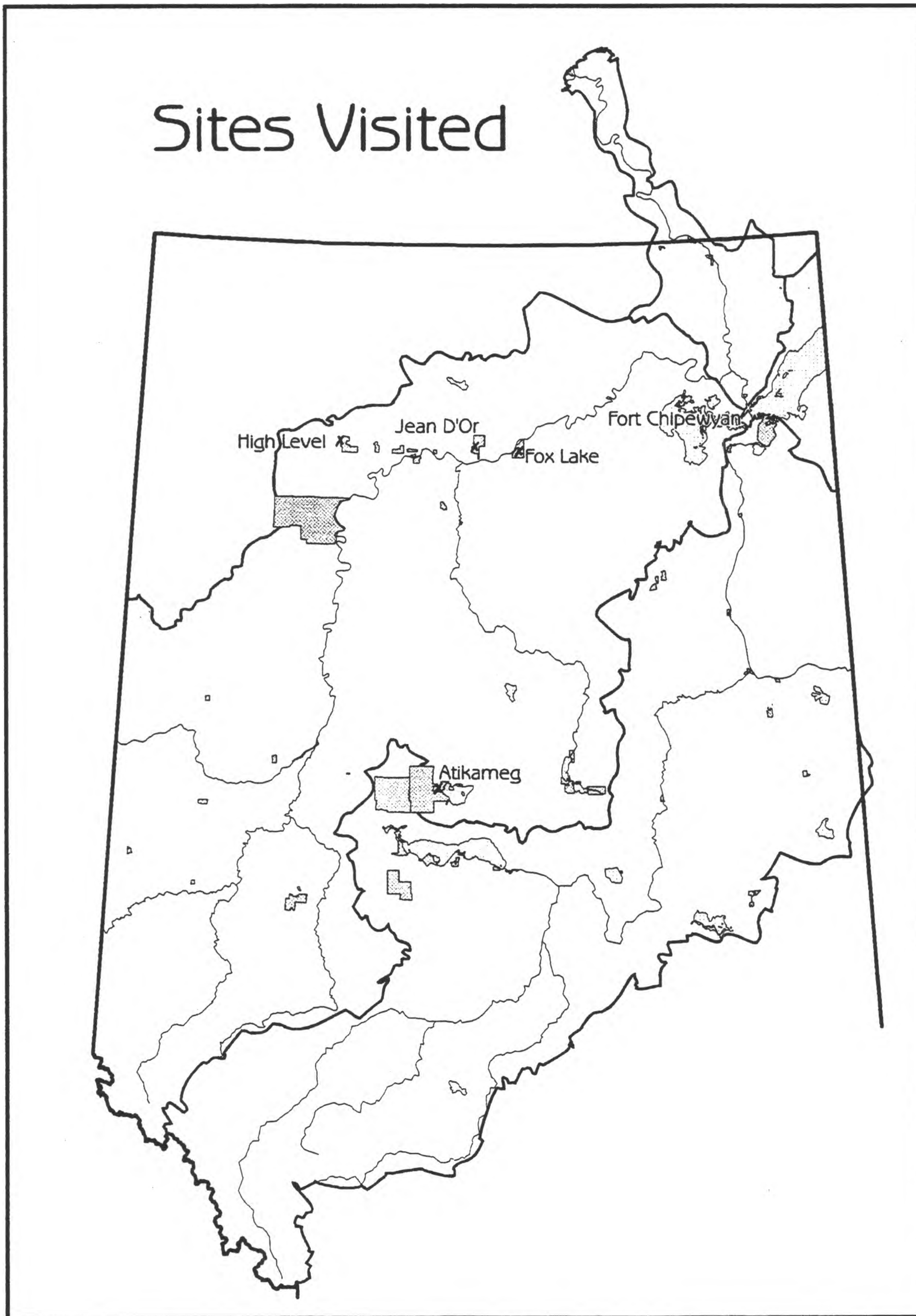


Figure 1. Sites Visited in Assessing Non-Conventional Drinking Water in the NRBS Area

3. FINDINGS AND RESULTS

3.1 HEALTH IN THE NORTHERN RIVER BASINS STUDY AREA

The World Health Organization (WHO) has defined health as a fundamental human right for a state of complete physical, mental, social and spiritual well-being (WHO, 1978). Therefore, determining the health of an area is a very complex task that requires an in-depth analysis of many factors of life of the people it is trying to assess. The Human Health Committee of the NRBS is involved in a Human Health Study that is set up to assess the health in the Basins based on the analysis of health records (Huberman, 1995). It will be interesting to look at this assessment of Health in the Northern River Basins at the completion of their study.

In a 1994 NRBS Health Records Study by Emde et al., researchers found that there appeared to be a higher incidence of selected waterborne diseases in some of the Northern River Basins Study area Health Units compared to the provincial averages. They concluded that "although incidences of some diseases were higher, in many cases the differences were not significant and residents generally do not appear to have substantially higher risks from waterborne diseases in the study area compared to the rest of Alberta (Emde et al., 1994)." This conclusion was reached based on the assessment of health record data from seven Alberta Health Units and Annual Notifiable Disease Summaries provided by Alberta Health. The main limitation with this was that Health Canada records were not included in the analysis. It is very likely that the conclusions may have been different if the Health Canada databases had also been assessed because there is a high native population in the NRBS area and health care on the reserves is administered by Health Canada (Bingham, 1994).

There are approximately 228 300 people living in the Northern River Basins Study area (Prince et al., 1994). There are many Indian Reserves in the NRBS area and therefore a significant proportion of this population is of native descent. It is well established that the native population in Canada experiences more ill-health than the rest of the Canadian population (Fraser-Lee and Hessel, 1994; Robinson and Heinke, 1990; Weller and Manga, 1987). Life expectancy for native Canadians is ten years less than the national average, and the infant mortality rate is more than double the rate for Canada as a whole (Fraser-Lee and Hessel, 1994). Epstein (1982) has likened the health of the Native population to that of "developing societies within developed countries" and Postl et al., (1987) observed that the health of the Canadian Aboriginal people is "perhaps the largest public health problem our country faces (Fraser-Lee and Hessel, 1994)."

However, results from a survey administered by the Traditional Knowledge Component of the Northern River Basins Study showed that "overall, respondents tended to be positive about their health with an average rating of 2.8 on a scale of one (excellent) to five (poor) (Traditional Knowledge Component, 1995)." Respondents in this survey were asked to cite any illnesses that were increasing or decreasing in their communities. The most common responses were an increase in cancer (59%), an increase in diabetes (25%), and an increase in heart problems (17%) (Traditional Knowledge, 1995). So, although the majority of the First Nation's people interviewed in this survey rated their own health positively, many of them also indicated a rise in several diseases in their communities.

3.2 DRINKING WATER AND HEALTH

Water is a basic human need and it is essential to sustain life. The links between water and health are numerous and the interactions are complex (WHO, 1993). As mentioned the World Health Organization defines health as a fundamental human right and states that to maintain health, a safe supply of drinking water is necessary (WHO, 1978).

The average daily consumption of drinking water for a Canadian adult is about 1.5 litres a day (Environmental Health Directorate, 1991). This consumption rate varies widely among individuals depending on attributes such as body weight, ambient temperature, diet, activity, culture, clothing and health status (McJunkin, 1982). If an average person is assumed to live for 75 years, that means that we will consume approximately 43172 L of water in our lifetime. From this, it can be seen that water can be an important vehicle for contaminants to enter our body over a lifetime. Therefore, not only is water physiologically necessary for survival, but the physical, chemical and microbiological constituents of the water that we consume can significantly impact our health.

Water Related Diseases

As stated by the World Health Organization, "infectious diseases caused by pathogenic bacteria, viruses and protozoa or by parasites are the most common and widespread health risk associated with drinking water (WHO, 1993)." The role of water in the chain of disease transmission has provided a basis for classifying water related diseases into one of four categories:

1. *Waterborne diseases* are transmitted by the ingestion of contaminated water whereby the infectious agent is passively carried in the water supply.
2. *Water-washed diseases* are related to poor sanitation and hygienic practices that are often associated with an insufficient quantity of water. This unavailability of water contributes to eye and skin diseases as well as the transmission of diarrheal diseases.
3. *Water-based diseases* are those in which the pathogen is dependent on the water supply or upon aquatic organisms for part of its life cycle.
4. *Water-vectored diseases* are transmitted by disease causing insects that breed in water (Cairncross and Feachem, 1993).

For the purpose of this study, this report will focus on waterborne diseases that are a result of consuming contaminated drinking water. Waterborne diseases are directly transmitted when water is consumed or used in the preparation of food and these diseases have the greatest health impact worldwide (Cairncross and Feachem, 1993). The probability of aquiring a waterborne disease is a statistical question related to many variables. McJunkin (1982) lists some of the variables involved:

1. The type of pathogenic organism.
2. The virulence of the specific strain.
3. The number of viable cells ingested.
4. The age of the victim (infants and elderly are generally more suseptible).

5. General health of the victim (sick and immunocompromised individuals are more suseptible).
6. Immunity of the individual to the organism.
7. And many other factors such as synergistic relationships between the organism and other organisms that may also be present.

From this list, it is evident that there are many factors to consider when determining the likelihood of an individual waterborne disease event. One thing that is for certain though, is that each year four million children under the age of five, and one million adults worldwide, die from diarrheal diseases (Cairncross and Feachem, 1993). Many of these deaths are likely a result of consuming contaminated drinking water.

3.2.1 Waterborne Diseases

Waterborne diseases are illnesses in which a pathogen (a disease causing agent or microorganism) enters the body as a passive component of drinking water. "Waterborne diseases can be further categorized as those due to microbiological organisms and those due to inanimate toxic substances suspended or dissolved in the water" (McJunkin, 1982). Microbiological waterborne diseases are generally acute and episodic, whereas illnesses caused by chemical agents may be acute, but normally result from long term ingestion at low concentrations.

3.2.1.1 Microbial agents

Microbial risks in drinking water stem from a wide range of bacterial, protozoan, viral and fungal disease agents. Sources of these waterborne organisms in a watershed include discharges from humans, wild and domestic animals, industry and storm water runoff events (Geldreich, 1991). The transmission of waterborne disease can be by primary or secondary routes. The primary route of infection is through the direct consumption or inhalation of water that contains the pathogen. Secondary routes of infection occur by consuming food that is washed by contaminated water or through contact with an infected individual. (Emde et al., 1994). Disease causing microorganisms can be further classified as being direct or opportunistic pathogens. Direct pathogens can cause disease in a normal healthy individual. On the other hand, opportunistic organisms generally form part of the normal micro-flora of the body, but given the correct conditions, may be capable of causing an infection in a compromised individual (Geldreich, 1991).

In the report Health Records Study for the Northern River Basins Project by Emde et al. (1994), the authors have included a compilation of characteristics of selected waterborne microbial pathogens that could be found in Northern Alberta Rivers. Information on the pathogenicity, infectious dose, range of symptoms, potential risk groups, and vehicle of transmission is included for each microorganism. This table has been included in Appendix A.

Bacterial Pathogens

Bacteria are single celled organisms that have a single chromosome without a nuclear membrane. Surface features that may be present include slime layers, capsules, and organs for motility (McFeters, 1990). These adaptations make bacteria particularly resistant to adverse conditions. Mechanisms of disease for bacterial pathogens are either by growing within our bodies and competing for nutrients with beneficial bacteria or by secreting toxic compounds (Gabler, 1988). Some of the more common waterborne bacterial agents are described below.

Cholera is an acute illness caused by *Vibrio cholerae* colonizing the small intestine. *Vibrio cholerae* produces a protein enterotoxin that is responsible for the rapid depletion of extracellular fluid and electrolytes caused by the abrupt onset on watery diarrhea, vomitting, and decreased blood pressure. The incubation of *Vibrio cholerae* is 6 to 48 hours (McJunkin, 1982).

Pathogenic strains of *E. coli* are a major cause of diarrhea. Due to the large infectious dose of 10^6-10^9 organisms, *E. coli* diarrhea is spread by contaminated food and water. Enterotoxigenic *E. coli* (ETEC) diarrhea is a common childhood illness in developing countries although it can also be found in more developed areas where the sanitation is poor (McJunkin, 1982). After an incubation period of 6 to 36 hours, ETEC attaches to the wall of the small bowel and produces two kinds of toxins. These toxins are the agents responsible for diarrhea, abdominal cramps, nausea, vomitting myalgias and fever that may ensue. The duration of the disease is from 1 day to 2 weeks (Craun, 1986).

Most salmonella based diseases are food borne rather than water borne, but waterborne transmission is certainly a possibility (AWWA, 1990; Craun, 1986). There are over 2200 serotypes of salmonella that are pathogenic to humans (AWWA, 1990). Most salmonella illnesses are "acute, infectious, bacterial disease with sudden onset of abdominal pain, diarrhea, nausea, fever, and sometimes vomitting (McJunkin, 1982)." These symptoms are manifested after a 6 to 48 hour incubation period in the colon, and the symptoms generally last for 2 to 5 days (McJunkin, 1982). Typhoid and paratyphoid fevers are also caused by strains of salmonella. The incubation period for typhoid is 10 to 14 days but may be as long as 60 days (Mosby Medical Encyclopedia, 1986) and the illness can last from 1 to 8 weeks with recurrances (Craun, 1986). *S. typhi* and *S. paratyphi* invade the intestinal mucosa, replicate in lymph nodes and eventually enter the bloodstream. Fever, headache, malaise, anorexia, constipation and/or diarrhea, and rashes are a few of the symptoms that accompany *S. typhi* and *S. paratyphi* infections (Craun, 1986).

Twelve to 48 hours after a strain of shigella has infected a human, symptoms including mild watery diarrhea, dysentery, fever, and grossly bloody stools may occur. One of four strains of shigella penetrates the colon and causes ulceration and colitis which in turn is responsible for the symptoms described above. Shigellosis, or bacilliary dysentery, ordinarily lasts for one week (Craun, 1986).

Campylobacter enteritis is a result of being infected with the bacteria Campylobacter jejuni and results in diarrhea, abdominal pain, malaise, fever, nausea, vomiting and bloody stools. The incubation period for *Campylobacter* is 2 to 5 days and the illness generally lasts less than a week (Craun, 1986).

Although *Legionella* species are residents of many water supplies, little evidence exists suggesting that the ingestion of water containing *Legionella* leads to infection (AWWA, 1990). Rather, it seems that the inhalation of these organisms causes pneumonia like symptoms in suseptible individuals. Initially, an influenza type of illness occurs followed within one week by high fevers, chills, headaches, muscle aches, dry coughs and diarrhea. (Mosby Medical Encyclopedia, 1986)

"*Mycobacterium tuberculosis* causes tuberculosis in humans. It is typically transmitted via person to person contact; however, sewage-contaminated water is a potential pathway (AWWA, 1990)." Initially the symptoms include chest pain, loss of appetite, fever and weight loss. As the disease progresses, night sweats, bleeding in the lungs, coughing up puss and blood and shortness of breath develop (Mosby Medical Encyclopedia, 1986).

The role of *Yersinia enterocolitica* in waterborne disease transmission is uncertain. Onset on symptoms occur 3 to 7 days after infection with the organism. The symptoms are age dependant and range from mild gastroenteritis to pseudoappedicitis. The duration of the illness is ordinarily 5 to 7 days (Craun, 1986).

Opportunistic bacteria are a heterogenous group of bacteria that do not cause disease in normal healthy individuals but can cause disease in suseptible individuals including infants, elderly, and immunocompromised people (AWWA, 1990). The AWWA (1990) lists *Pseudomonas*, *Aeromonas hydrophilia*, *Edwardsiella*, *Flavobacterium*, *Klebsiella*, *Enterobacter*, *Serratia*, *Proteus*, *Citrobacter* and *Acinetobacter*, among others, as opportunistic pathogens.

Protozoan Agents

Protozoans are single-celled animals that lack a cell wall and are more complex than bacteria (AWWA, 1990). Pathogenic protozoans of particular interest in drinking water are *Giardia*, *Cryptosporidium* and *Entamoeba histolytica*.

The wilderness illness many people call "Beaver Fever", is actually a protozoal disease called giardiasis. *Giardia* is a single celled flagellated protozoan that can exist as a trophozoite, 9µm x 21µm, or as an ovoid cyst, 6µm x 10µm (AWWA, 1990). *Giardia* are the most common identified etiological agent of all waterborne outbreaks and are found in water as a result of the deposition of fecal material of both man and animals (Rose et al., 1991). *Giardia* organisms infect many domestic and wild animals, including dogs, cats, rats, muskrats and beavers to name a few (Jakubowski et al., 1985). In less populated areas, animal vectors likely play a larger role in the contribution of *Giardia* to the environment. In a human dosing experiment by Rendtorff and Holt in 1954, they demonstrated that infection was initiated by the ingestion of as few as 10 cysts (Rose et al., 1991). One to three weeks after *Giardia* is consumed, an infected individual may develop symptoms of chronic diarrhea, abdominal cramps, frequent loose, pale, malodourous stools, fatigue and weight loss. If untreated the illness can last for two to three months, but sometimes it can persist for years (Fogel, 1982). In any case the illness to infection ratio is highly variable and depends on the individual (Rose et al., 1991). Hygiene education, proper sanitation and proper drinking water treatment are effective control measures in reducing the risk of *Giardia* infections.

"*Cryptosporidium* is widespread in the environment. Oocysts have been found in rivers, and streams, lakes and reservoirs, raw and treated sewage, and treated surface waters. The organism has been found in cattle, sheep, swine, goats, dogs and cats as well as deer, raccoon, foxes, coyotes, beavers, muskrats, rabbits and squirrels. Consequently, animals typically found in watersheds may serve as sources of infection for humans, shedding oocysts that eventually appear in source waters (Pontius, 1994)." The infective dose for humans is not known, but studies to date indicate that as few as 10 or perhaps as many as 500 oocysts are required to initiate infections in mammals (Pontius, 1994). After an incubation period of 2 to 12 days, diarrhea, abdominal cramps, nausea, vomitting and low grade fever develop (Pontius, 1994). The length of illness typically lasts 10 to 14 days but can last for much longer. Presently there is no cure for cryptosporidiosis which means that *Cryptosporidium* infections are life threatening for immunocompromised individuals.

Amebiasis is a result of the cysts of *Entamoeba histolytica* inhabiting the colon and invading the colonic mucosa. The onset of symptoms occurs after an incubation period of 2 to 4 weeks. The symptoms include mild gastroenteritis, frank dysentery, fever and grossly bloody stools (Craun, 1986). Sometimes *Entamoeba histolytica* can enter the bloodstream, reach other organs and cause amoebic abscesses (AWWA, 1990). Unlike *Giardia*, *E. histolytica* is not carried by animals so the potential of contamination of waters in remote areas is low. But, it is estimated that 3 to 10% of the population carries *E. histolytica*, so proper sanitation is important even in isolated locations.

Viral Agents

Viruses are 10 to 25nm particles composed of a packet of genetic material surrounded by an outer protein coat and are characterized by their dependence on host cells to reproduce (AWWA, 1990). There are over 100 types of enteric viruses that infect the GI tract of humans. Viruses of importance in drinking water include Hepatitis A, Norwalk viruses and Rotaviruses (AWWA, 1990).

Evidence of the waterborne route of infection is the strongest for Hepatitis A virus (HAV) compared to all other viruses (AWWA, 1990). Hepatitis A virus infects hepatocytes causing imflammation and necrosis of the liver (Craun, 1986). After a 2 to 6 week incubation period, the infected individual may develop a fever, nausea, diarrhea, malaise and jaundice (Craun, 1986). These symptoms generally last for 1 to 2 weeks. Norwalk type viruses create short lived infections; both the incubation period and the duration are 1 to 2 days. Infection by these viruses causes the abrupt onset of gastroenteritis, with vomitting in children and diarrhea in adults, and headaches for some people (Craun, 1986). Rotavirus is another viral agent that can be asymptomatic or cause severe gastroenteritis with significant dehydration requiring hospitalization. The incubation period for rotavirus is 1 to 3 days and the illness usually lasts from 2 to 5 days (Craun, 1986).

Unknown Etiology

Despite the vast numbers of bacterial, viral and protozoan organisms that are known to cause illness if consumed in sufficient quantities, there are still many unknown microbiological agents of disease. There are also many cases in which an individual is sick and may have many of the symptoms described above, but for which the exact cause of the illness is unknown. In the 1986 to 1990 notifiable disease statistics for Alberta analyzed by Emde et al. (1994) one of the categories was "Unspecified Diarrhea". This means that an individual presented to the health care facility with diarrheal symptoms, but the exact cause of the diarrhea was not determined. This could be because, stool and water samples were never investigated and if they were, it could be because an etiological agent was not detected. Furthermore, microorganisms are not the only agents that are responsible for diarrhea. Sometimes, physical and chemical parameters can also cause such symptoms.

3.2.1.2 Chemical agents

"Water, the universal solvent, contains a wide array of chemicals, even in its natural condition. The chemical quality of water varies from place to place because of the different environments through which various water sources pass (Grover and Zussman, 1985)." The long term chronic ingestion of low levels of chemical contaminants in drinking water has been associated with adverse health effects in some cases. The AWWA (1990) outlines a variety of adverse health effects depending on the chemical concentration and length of exposure to a particular chemical:

> "Toxic: Causing a deleterious response in a biological system, seriously injuring function, or producing death. These effects may result from acute conditions (short high-dose exposure), chronic (long-term, low-dose) exposure or subchronic (intermediate-term and dose) exposure.
> Neurotoxic: Exerting a destructive or poisonous effect on nerve tissue.
> Carcinogenic: Causing or inducing uncontrolled growth of aberrant cells into malignant tumors.
> Mutagenic: Causing heritable alteration of the genetic material within living cells.
> Teratogenic: Causing nonhereditary congenital malformations (birth defects) in offspring."

The International Agency for Research on Cancer also has a system of classifying chemicals according to their carcinogenicity (NRC, 1983):

Group 1: Known human carcinogen
Group 2A: Probable human carcinogen
Group 2B: Possible human carcinogen
Group 3: Not classifiable
Group 4: Not carcinogenic

Although the health effects of some waterborne chemicals have been established with certainty, there are many health effects that have not been established. This is because much of the work on the chemical contaminants in water is based on toxicological data that is derived from animal experiments. The extrapolation of data obtained from animal experiments to human effects definately has its limitations. Although some epidemiological data is available on human exposure to a variety of chemicals, much of the health effects information for many chemicals is inadequate and inconclusive. Unfortunately, however, for many of the chemicals which may be detected in water there is not even a good toxicity data base from laboratory animal studies.

Basically, chemicals in drinking water can be considered as being either inorganic or organic. The following sections of this report will focus on the adverse health effects that can occur from the ingestion of excessive amounts of these potentially waterborne chemicals.

Inorganic Chemicals

Inorganic contaminants are a class of chemicals that generally do not contain carbon. Heavy metals, nitrates, sulphates and other salts are included in this category.

Metals

As Figure 2 illustrates, metals make up a large percentage of the earths elements.

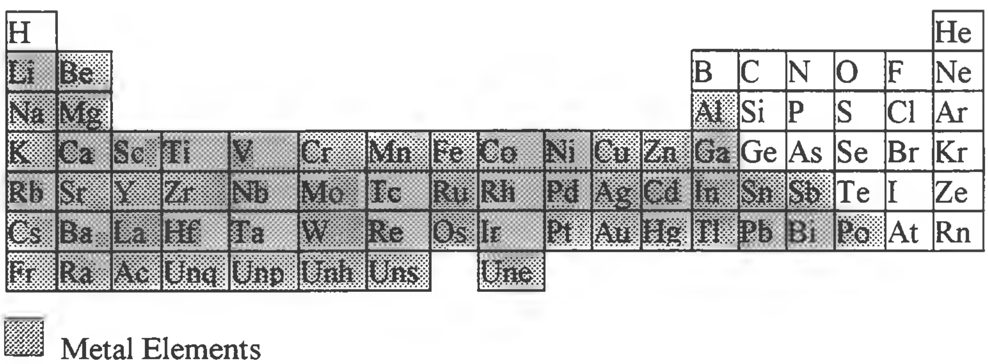


Figure 2. Metallic Elements in the Periodic Table.

The health impacts of some common metals that may be found in drinking water are discussed below.

A link between Aluminum consumption and Alzheimers disease has been hypothesized, but there are no conclusive studies to date (AWWA, 1990). Long term chronic exposure may create weakness, bone pain and anorexia (AWWA, 1990). As a result of these possible health effects there has been increased attention given to Aluminum in drinking water treatment plants that use Alum in a coagulation step.

Barium in waters occurs both naturally and as a result of man's activities. Barium can be introduced into a water supply from oil and gas drilling muds, coal power plants, jet fuels and automobile paints (AWWA, 1990). Although the carcinogenicity of barium has not been established, barium in drinking water has demonstrated hypertensive tendencies in animal studies (AWWA, 1990).

Cadmium has been classified as a probable human carcinogen via the inhalation route, but not by ingestion. However, the ingestion of cadmium can cause renal dysfunction (AWWA, 1990).

Chromium occurs in two valence states. Chromium III is an essential nutrient whereas Chromium VI is toxic and causes damage to the liver and kidneys and results in internal bleeding and cuts on the skin. Although Chromium VI is classified as a human carcinogen, it does not exhibit carcinogenic effects by the ingestion route (AWWA, 1990)

High doses of copper can cause acute gastrointestinal disturbances, liver and kidney damage and anemia (AWWA, 1990).

The health effects of excessive lead consumption are well documented, and as a result, lead has been classified as a probable human carcinogen. Excessive lead in the body interferes with red blood cell synthesis thereby causing anemia, kidney damage, impaired neurological and physical development, and high blood pressure (AWWA, 1990).

Mercury is found in two forms in the aquatic environment. In the water phase, mercury is an inorganic salt that is poorly adsorbed in the GI tract. However, sediments and fish contain organic methyl mercury that targets the central nervous system and can cause impaired mental and motor functions or even death (AWWA, 1990).

Other Inorganic Chemicals

Total Dissolved Solids are comprised of inorganic salts such as calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates and small amounts of organic matter dissolved in water (WHO, 1993). Excessive high levels of some of these salts can cause adverse health effects. A high sodium intake, for example, has been implicated with high blood pressure and heart disease. And high concentrations of sulfate in drinking water can result in acute diarrheal symptoms (AWWA, 1990)

Nitrates in a water supply may indicate sewage infiltration or decomposing matter. Although nitrate can be found in surface waters (generally between 1 and 2mg/L), it is mostly in ground waters (Levallois and Phaneuf, 1994). An important cause for the increase in the concentration of underground nitrates is the use of agricultural fertilizers. The transformation of nitrates to nitrites in humans can cause methemoglobinemia, particularly in children. Nitrites oxidize the iron component of hemoglobin so that its oxygen carrying capacity is diminished and anoxia and death can then occur (Levallois and Phaneuf, 1994). Secondly, the formation of N-nitroso compounds from nitrites might be responsible for an increased risk of cancer although this is not well established.

Ammonia in the environment originates from metabolic, agricultural, industrial processes and from disinfection with chloramines (WHO, 1993). Natural levels are usually below 0.2mg/L. Anaerobic ground waters may contain up to 3mg/L. Ammonia is an indicator of possible bacterial, sewage or animal waste pollution. Ammonia is not of immediate health relevance, however, it can compromise disinfection, result in nitrite formation, and can cause taste and odour problems (WHO, 1993).

Inorganic Chemicals Associated With Chlorine Disinfection

The primary disinfectant in the drinking water treatment industry is chlorine. Chlorine combines with water to form hypochlorous acid which then ionizes to form hypochlorite ion and, if ammonia is present, chloramines (AWWA, 1990). The World Health Organization (1993) reported that there were no adverse health effects associated with either chlorine itself or the chloramines. It should be noted here that some adverse effects on health are associated with some organic disinfection by-products that are formed as a result of chlorine disinfection, but these are discussed in the following section of this report.

Organic Chemicals

Organic chemicals are made up of one or more carbon atoms along with other elements (Gabler, 1988). Organic constituents in water are derived from three major sources. First, the majority of organics in the water originate from the natural decay of animal and vegetable matter and includes humic substances, microorganisms, and various hydrocarbons. Second, pesticides, solvents, and plasticizers are a few man-made organic contaminants derived from domestic and commercial activities. Most of the adverse health effects associated with organic contaminants are a result of chemicals from this group. And third, organic chemicals are generated as a result of water treatment and distribution, including disinfection by-products and haloacetonitriles to name a few.

Table 1. Some Potential Organic Contaminants of a Water Supply

Naturally Occuring Organics	**Volatile Organic Chemicals**	**Synthetic Organic Chemicals**	**Organic Disinfection By-Products**
Humic materials	Benzene	Acrylamide	Chloroform
Microorganisms	Carbon Tetrachloride	Alachlor	Dibromochloromethane
Microbial metabolites	Dichlorobenzene	Aldicarb	Dichlorobromomethane
Aliphatic hydrocarbons	Ethylene dichloride	Atrazine	Bromoform
Aromatic hydrocarbons	Vinylidene chloride	Carbofuran	Dichloroacetic acid
	1,2-Dichloroethylene	Chlordane	Trichloroacetic acid
	Methylene chloride	Dibromochloropropane	Haloaldehydes
	Perchloroethylene	1,2-Dichloropropane	Chloroacetaldehyde
	Trichlorobenzene	Dinoseb	Trichloroacetaldehyde
	Methyl chloroform	Endrin	Haloketones
	Trichloroethylene	Epichlorohydrin	Haloacetonitriles
	Vinyl chloride	Ethyl Benzene	Chloropicrin
	Paradichlorobenzene	Ethylene Dibromide	Chlorophenols
		Heptachlor	2,4-Dichlorophenol
		Lindane	2,4,6-Trichlorophenol
		Methoxychlor	
		Polynuclear aromatic hydrocarbons (PAHs)	
		Polychlorinated biphenyls(PCBs)	
		Pentachlorophenol	
		Simazine	
		Styrene	
		2,3,7,8-TCDD (Dioxin)	
		Silvex	
		Toluene	
		Toxaphene	
		Xylene	

(Source: Adapted from AWWA, 1990)

Table 1 lists some organic contaminants that may be found in water supplies. Due to the large number of chemicals listed, an overview of the health effects associated with each of these contaminants is beyond the scope of this study. Interested readers are referred to AWWA's book Water Quality and Treatment: A Handbook of Community Supplies from which this list was compiled for more information.

The health effects of organic disinfection by-products is relevant to this report because a growing number of people are choosing alternative sources of drinking water based on the health risks that have been associated with the disinfection by-products of chlorination. The trihalomethanes of importance in drinking water are chloroform, bromodichloromethane, dibromochloromethane, and bromoform (WHO, 1993). Bromoform, dibromochloromethane, and bromodichloromethane are all readily absorbed from the gastrointestinal tract and all three have been found to cause liver and kidney damage in experimental animals. Chloroform has been found to induce liver cancer in laboratory animals and it also affects renal functioning and causes changes in the thyroid. Even though there are a number of epidemiological (and scientific) studies that point to an association between chlorinated drinking water and mortality from cancer, no definitive conclusions have been drawn due to the large numbers of confounding factors such as smoking and diet that were unaccounted for in many of these studies (AWWA, 1990). Therefore, IARC has classified both bromodichloromethane and chloroform in Group 2B which means that they are possibly carcinogenic to humans (WHO, 1993). It should also be noted that the risks associated with these by-products are small in comparison with the risks associated with inadequate disinfection and it is important that disinfection should not be compromised in attempting to control such by-products.

3.2.2 Public Health Protection

Currently, there is a considerable public health debate on balancing the risks of waterborne microorganisms versus health risks from disinfection by-products. One side argues that too much disinfectant is being added to the water resulting in the formation of an excessive amount of trihalomethanes, some of which are considered possible human carcinogens. The arguement of the other side is that waterborne microbial contaminants are a more immediate health threat and must be stringently controlled. Although the WHO recognizes the potential and predicted risks associated with disinfection by-products, they state that "in terms of water quality, pathogenic microorganisms remain the most important danger to drinking water in both developed and developing countries (WHO, 1993)." Emde et al., (1994) reiterate this by saying that "compared with the potential or predicted risks associated with exposure to chemicals in water, the actual or documented health risks associated with microbes are extremely high." There is another angle to this arguement in that the "secondary spread of infectious diseases is a unique feature of microbial risks that has no parallel in chemical risks from drinking water and requires special attention (Sobsey et al., 1993)."

From the health effects discussion in the previous section, and the extensive list of potential waterborne contaminants that exist, it is clear that the levels of both chemical and microbial contaminants in drinking water must be controlled to ensure the protection of public health. It is for this reason that Guidelines for Canadian Drinking Water Quality (GCDWQ) were established. In these guidelines, limits have been set for physical, chemical, microbiological and radiological contaminants that could have an adverse impact on health.

3.3 DRINKING WATER QUALITY

The Guidelines for Canadian Drinking Water Quality have established limits on the levels of various physical, chemical, microbial and radiological parameters (Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1993). The establishment of drinking water quality guidelines helps to answer the question of whether or not a particular water source is safe to drink. The levels of various parameters in the water supply are measured and the levels compared to regulations, guidelines and known health risks to assess the safety of a particular source. It is assumed that if the water supply in question meets all of the recommended levels set in these guidelines, that the quality is good, and that the water is safe to drink.

3.3.1 Drinking Water Quality Guidelines

The regulation of drinking water falls under the jurisdiction of the province, but in the Northern River Basins Study area, there are a couple of National Parks and several Indian Reservations which are regulated by the federal government. Health and Welfare Canada has published the Guidelines for Canadian Drinking Water Quality (GCDWQ) which were established to specify recommendations and limits for substances that affect the quality of drinking water (Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1993). As outlined in Alberta Environment's Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems: Section 4.4, the health related standards of the GCDWQ should be met to ensure that community drinking water supplies and treatment systems provide a high level of public health protection (Alberta Environment, 1988). Although the Guidelines are enforceable for community water systems, non-community and therefore, non-conventional water systems are not regulated by these guidelines.

Within the GCDWQ, a parameter is assigned a guideline value if the assessment of data on the contaminant of concern indicates a need to set a numerical guideline on the constituent, for health or other reasons. Chemical, physical, microbiological and radiological parameters in the GCDWQ are assigned a Maximum Acceptable Concentration (MAC), an Interim Maximum Acceptable Concentration (IMAC), and/or an Aesthetic Objective (AO). "Maximum Acceptable Concentrations have been established for certain substances that are known or suspected to cause adverse effects on health (Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1993)." MAC's are derived to protect health based on the assumption of lifelong consumption of the substance at the established guideline concentration. Interim Maximum Acceptable Concentrations (IMAC) are set for substances that are assumed to have an adverse effect on health but for which there is insufficient toxicological data to set an MAC with reasonable certainty. Larger safety factors have been employed to compensate for the uncertainties for these substances. Aesthetic Objectives are applied to parameters that affect the acceptablility of the water by consumers and so that a good quality of water can still be supplied. If the concentration is well above an aesthetic objective, there is a possibility of a health hazard.

Appendix B contains a concise summary of the physical, chemical, microbiological and radiological parameters regulated in the 1993 Guidelines for Canadian Drinking Water Quality.

Physical Parameters

Physical parameters are the general properties of a composite water sample. That is, all of the elements in water contribute to the physical characteristics of the water sample. Some of the more common physical parameters that affect the aesthetic quality of drinking water are temperature, pH, total dissolved solids, taste, odour and colour. Taste and odour in drinking water may originate from biological processes, chemical contaminants, and as a by-product of treatment (WHO, 1993). Water temperature influences the perception of taste and odour. Generally, cooler water is preferred by consumers (WHO, 1993). The colour in water can be from many sources. Humic and fulvic acids are coloured organic matter that add colour to the water. The presence of iron and other metals also influences the colour of the water. And of course, industrial effluents sometimes contribute to the colour in a water supply (WHO, 1993). Total dissolved solids (TDS) are a measure of the concentration of dissolved inorganic solids in the water. pH is another physical parameter that is measured and provides insight into some of the internal processes that may be going on in the water. pH is a measure of the hydrogen ion concentration in the water and is measured on a scale from 0 (acidic) to 14 (alkaline). All of these parameters have been assigned AO values in the GCDWQ.

Turbidity is one physical parameter of particular importance in the assessment of drinking water quality that has been assigned a MAC. Turbidity is a direct indicator of clarity and is caused by suspended particulates in the water such as clay, silt, finely divided organic and inorganic matter, and microorganisms (Letterman, 1994a). "Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample (American Public Health Association et al., 1992)." The reason that turbidity has been assigned a MAC is because "the presence of turbidity can significantly affect both the microbiological quality of the drinking water and the ability to detect bacteria, viruses and protozoa. Waterborne bacteria, viruses and protozoa can be embedded in, or adhered to, particles in the raw water, or they can become trapped within floc formed during water treatment. Thus, turbid finished water can contain undesirable microorganisms that may not be detectable, or that may be grossly underestimated by current detection methods (Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1993)." Furthermore, the disinfection process can be hindered by turbidity-causing material in the water because enmeshed microorganisms are protected from chemical disinfectants and are even provided with a nutrient source by the presence of these particles (WHO, 1993; Letterman, 1994b). The MAC for turbidity is 1 NTU although a tubidity of 5NTU is acceptable if it can be shown that disinfection has not been compromised (Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1993).

Microbiological parameters

The microbiological quality of drinking water is of particular importance to public health. It is evident from the discussion in Section 3.2 that the potential number and types of pathogens in a water supply is extensive. Although techniques are available to identify and enumerate most of the common types of pathogens found in water, due to the large numbers and types that can be found, this is not always practicable when monitoring drinking water supplies (McJunkin, 1982). Therefore, when assessing the microbiological quality of potable water, indicator organisms are used as an indirect measure of pathogens in the water.

At least three simple requirements should be satisfied in order for an agent to be considered an indicator organism. First, indicator organisms should be present in sewage and polluted water where pathogens are present. Second, the population of indicator organisms should be correlated with the degree of pollution. Third, indicator organisms must be easily and quickly identified and enumerated in simple lab procedures (McJunkin, 1982). If these criteria are met, then the organism is a good indicator of the presence of microbial pathogens in a water supply. The coliform group of microorganisms are common indicator organisms used in the assessment of the microbiological quality of potable water.

Total Coliform (TC) organisms are gram-negative, rod shaped bacteria that ferment lactose at 35 to 37°C with the production of acid, gas and aldehyde within 24 to 48 hours and are capable of growth in the presence of bile salts or other agents with similar growth inhibiting properties (McJunkin, 1982). Coliform bacteria are members of the *Enterobacteriaceae* that are usually found in the intestinal tract of warm-blooded animals. Although this group is limited in its ability to indicate fecal pollution, (because there are non-fecal bacteria that fit the coliform definition as well) monitoring for Total Coliforms is still important to assess the microbial quality of the water (WHO, 1993).

Thermotolerant Fecal Coliforms (FC) are a subset of the Total Coliform organisms that can ferment lactose at 44 to 45°C including the *Escherichia* genus and to a lesser extent species of *Klebsiella*, *Enterobacter*, and *Citrobacter*. It has been found that thermotolerant coliforms other than *E.coli* may also originate from industrial effluents, decaying plant matter and soil. Therefore, the common description of this group of bacteria as "Fecal Coliforms" is not an accurate one and instead they should be called Thermotolerant Coliforms (WHO, 1993).

The Canadian Drinking Water Quality Guidelines state that the general bacterial population and coliform bacteria should be monitored routinely. The maximum acceptable concentration for Total Coliforms (TC) is zero colony forming units per 100mL. However, due to the variation in the detection method of these organisms, compliance is considered when the following criteria is met:

1. "No sample should contain more than 10 total coliform organisms per 100mL. none of which should be fecal coliforms;
2. No consecutive sample from the same site should show the presence of total coliform organisms; and
3. For community drinking water supplies:

a) not more than one sample from a set of samples taken from the community on a given day should show the presence of coliform organisms; and
b) not more than 10% of the samples based on a minimum of 10 samples should show the presence of coliform organisms (Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1993)."

If any of these criteria are exceeded, corrective actions should be carried out which includes measures such as resampling, increasing disinfectant dosage, flushing water mains, utilizing an alternative source of water and advising consumers to boil their water.

The GCDWQ also require that the general bacterial population is assessed even though this general bacterial enumeration does not usually have a direct health significance (McFeters, 1990). The reason it must be monitored then is because excessive bacterial concentrations can hinder the recovery of coliforms, therefore preventing the detection of a potential health threat (Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1993; McCabe and Winton, 1990; and McFeters, 1990). There are two acceptable methods for enumerating the general bacterial population in the GCDWQ. One is to count the background colonies on the Total Coliform plate. If the number of non-coliform background colonies is greater than 200cfu/100mL, then the water should be resampled. The second acceptable measurement of the general bacterial population is a Heterotrophic Plate Count (HPC). The HPC is a measure of aerobic and facultative aerobic bacteria found in water that are capable of growth on simple organic compounds (primarily carbohydrates, amino acids and peptides) found in the culture medium, and under incubation times and temperature conditions specified (McFeters, 1990).

It has been argued that the limited coliform monitoring requirement in the GCDWQ is insufficient in terms of protecting public health. This is because there is a large spectrum of organisms that can survive conventional treatment processes including spore formers, acid-fast bacilli, pigmented organisms, disinfectant-resistant bacterial strains, various yeasts, fungi, and actinomycetes (AWWA, 1990). Therefore, sometimes, the regular coliform enumeration is supplemented by further microbiological assays. Currently, viruses and protozoa are under review for possible addition to the Guidelines for Canadian Drinking Water Quality (Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1993).

Chemical parameters

The Chemical parameters that are regulated in the Guidelines for Canadian Drinking Water Quality are either inorganic or organic. Metals and other non-carbon containing elements are considered inorganic. Organic chemicals, on the other hand, contain carbon in their structure. Pesticides and organic disinfection by-products are examples of chemicals that would fit into this classification. Appendix B lists the MAC, IMAC and AO limits set for various organic and inorganic chemical contaminants.

Radiological

Radioactivity is energy that is released from radioactive atoms. There are different forms of radioactive energy and each of these forms reacts differently within the human body (AWWA, 1990). Radiation can be naturally occuring or man-made. The USEPA has estimated that drinking water only contributes about 0.1% to 3% of a persons annual dose of radiation which is very small in relation to other exposures. Nonetheless, the GCDWQ has established limits for certain radiological parameters although these are currently under review.

Sampling and Monitoring

The frequency of bacterial sampling as set out in the Guidelines for Canadian Drinking Water Quality is not regulated, but it has been suggested that for systems that serve less than 5000 people, a minimum of 4 samples per month are taken (Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1993). This would account for the majority of the drinking water supplies in the Northern River Basins Study. Conventional drinking water treatment plants that serve larger populations are recommended to sample more often. Sampling for parameters that are assigned an aesthetic objective is to be decided by the appropriate control agency. Chemical and radiological substances in the Guidelines that have maximum acceptable concentrations should be sampled semi-annually. This frequency may be increased if the water is suspected to be polluted or decreased if substances are consistently absent. All sampling and analyses performed should be done following the protocols set out in Standard Methods for the Examination of Water and Wastewater (American Public Health Association et al., 1992).

3.3.2 Existing Drinking Water Quality Data

The federal department of Health Canada is responsible for monitoring the quality of drinking water on Indian and Inuit reserves, in National Parks and in federally owned buildings and properties. The rest of the drinking water in the Northern River Basins Study area is monitored by Alberta Environmental Protection (AEP). As part of this monitoring, AEP initiates the *Treated Water Survey* in which municipally treated water is routinely sampled for 250 physical and chemical parameters. Although the assessment of microbial contaminants is not part of the *Treated Water Survey*, treatment facilities are required to sample for two indicator organisms in their license to operate (Prince et al., 1994).

A 1994 Drinking Water Component Report compiled, synthesized and summarized existing drinking water quality data for the NRBS area (Prince et al., 1994). In this study the analysis of data in the *Treated Water Survey* showed that chemically, the drinking water in the NRBS area meets health related guidelines with the exception of some trihalomethane violations (Prince et al., 1995). It should be noted that the *Treated Water Survey* does not include monitoring of microbial contaminants. To assess the microbial quality of drinking water in the NRBS area a follow up study by the same researchers was undertaken. Work carried out in this study involved analyzing historical

Total and Fecal Coliform data, historical turbidity data and samples obtained from site visits to 38 facilities in the NRBS area (Prince et al., 1995) The preliminary findings of this study are that "small facilities produce poorer drinking water quality than larger facilities" and several small facilities have microbial counts that exceed values suggested in the GCDWQ (Prince et al., 1995).

To the best knowledge of the authors of this report, historical water quality data on some of the non-conventional sources of drinking water in the NRBS area such as water from snow and ice (and others that will be discussed in subsequent sections of this report) is not available. There has been one related study done by Alberta Environment in the Peace-Athabasca Delta called the *Drinking Water Survey* in which samples were taken at various remote locations where people claim to be using the water for consumptive purposes (Flett, 1994a). Although the sampling portion of this program is over, the data has not yet been compiled and is therefore unavailable at the time that this report was written (Jackson, 1995).

3.3.3 Water Quality Concerns in the NRBS Area

Results from Drinking Water Component Interviews

From talking to people in the areas visited during the course of this study, it was found that there is great concern over the quality of the drinking water in the Northern River Basins. Many of the people interviewed by Drinking Water Component Researchers in the Northern River Basins expressed an uneasiness about the practice of using chlorine in drinking water treatment. Stella Marten, a Fort Chipewyan resident, said that people prefer the taste of lake water because sometimes the taste of chlorine ("Perfex" or "Javex" as it is commonly called) is so strong because they put too much in (Marten, 1994b). Raymond and Yvonne Ladoucer (1994), also of Fort Chipewyan, confirmed this bad taste of chlorine and do not like drinking the treated water. They have a container by their sink in which they let their drinking water sit overnight to let some of this chlorine taste evaporate.

Aside from the bad taste of chlorine, people in the Northern River Basins Study area also associate a health risk with drinking chlorinated water. Ms. Marten (1994b) said that some people won't even drink the water from the Fort Chipewyan Water Treatment Plant because "they think that it would affect them more" than drinking water from the lake. She explained that it does not make sense to the people to "dump poison into their drinking water (Marten,1994b)." The same concerns were reiterated in Atikameg. Rosie Chalifoux (1995) said that she knows of people who think that the treatment plant water will clog their veins and others who claim to have become ill from the chlorine added to the treated water. Dwayne Laboucan (1994a), from Fox Lake, also mentioned that he suspects that many people do not drink the water from the treatment facility there. This is likely for some of the same aesthetic and health related concerns.

Residents of the Fort Chipewyan area feel that the rate of cancer in the area is rising and this may have something to do with drinking water (Ladoucer, 1994; Flett, 1994; Marten, 1994). Some of the people interviewed expressed their concern about the effect that the drinking water has on the health of their children. Researchers have noted one case in which a mother purchased bottled water for her child until he turned two years old because she was afraid of the effect that the chlorine would have on the baby's health. Other people talked about chronic illnesses that they think may be a result of drinking chlorinated water.

Besides drinking water from the treatment plant, many residents of the NRBS area also obtain drinking water from natural water bodies, particularly those that live in remote locations and live off of the land. Willie Courtoreille is a resident of Fort Chipewyan. He expressed a concern over the poor quality of the lakes and rivers in the area and thinks that this has resulted in a negative impact on drinking water. He attributes the degradation of the surface water quality to industrial pollution. He feels that the government has been bought out by industry and if a problem was found that the information would not be released. "And besides," he said, "the tourists don't drink it (Courtoreille, 1994b)." He proceeded to voice his concerns about the general quality of water in the area. He mentioned that they have been told not to eat the fish south of the 27 Base Line more than once a week. "Why, what's wrong with them?" he asks, "These are the same fish that are up here too (in the Fort Chip area). The fish swim and move from place to place. There isn't someone at the 27 Base Line telling them not to go any further. And that water is coming up here as well (Courtoreille, 1994b)" He is genuinely concerned about the quality of the water.

Many people living in remote areas have been forced to change their drinking water habits due to the poor aesthetic quality of the surface water. John and Lena Courtoreille have a cabin on Prairie River near Fort Chipewyan. They said that if they boil the river water for tea like they used to, that there is a brown foam on top and "it doesn't taste very good (Courtoreille, 1994a)." This is consistent with responses from the Athabasca River Basin Study in which respondents noted that even boiled water imposed a bad taste on the tea and foods being prepared (Ft. McKay Indian Band, 1988). Raymond Ladoucer (1994) also talked about this "foam" saying that tea or coffee prepared from this water would have a black foam on top. Speaking of foam, he also said that it was not uncommon to see 20 miles of foam on the river sometimes.

It is interesting to note that during these field trips, adverse health effects associated with microbial pathogens in drinking water was not a great concern to those interviewed.

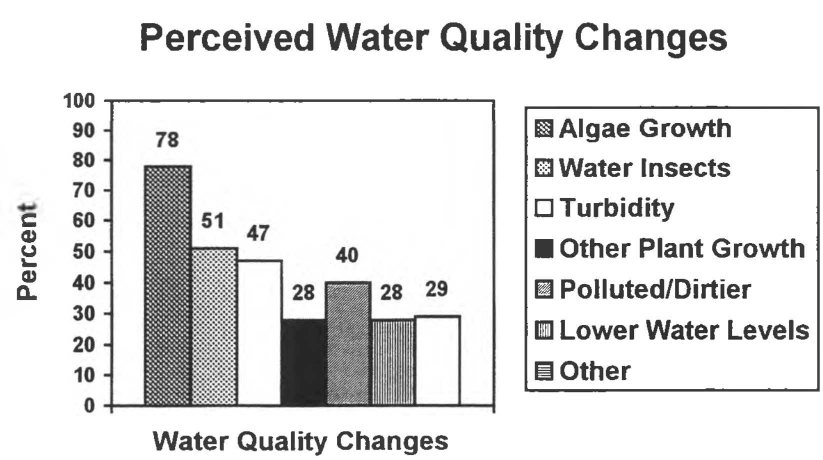
Results from Other Studies

In addition to the interviews carried out by the drinking water component in regards to water quality concerns of people that live in the Northern River Basins, two other related studies also addressed this issue. The first of these was the Northern Athabasca River Basin Study which was initiated and carried out by Chipewyan and Cree Indian Bands living in the Athabasca River Basin (Ft. McKay Indian Band, 1988). From this study it was concluded that "water quality degradation has imposed great changes on the use of the river for domestic, especially drinking water use and for fishing (Ft. McKay Indian Band, 1988)." The water quality degradation percieved by those interviewed in the study was deemed to be a result of oil sands operations, sewage effluents, and general upstream pollution (Ft. McKay Indian Band, 1988).

The second related study that addressed water quality concerns of the residents of the NRBS area was carried out by the Traditional Knowledge Component of the Northern River Basins Study. The Traditional Knowledge Component collected information through in-person interviews of 221 people from nine different native communities in the Northern River Basins. There was a qualifying criterion for respondents of the questionnaire in that they had to have lived a traditional lifestyle at some point in their lives (Traditional Knowledge Component, 1995). It is because of this criterion that the average age of respondents was 58 years old which is higher than for the northern adult population as a whole (Traditional Knowledge Component, 1995). Therefore, in the interpretation of the results of the Traditional Knowledge Component presented throughout this report, it is important to keep this selection criteria in mind and that the results may not necessarily reflect all segments of the population in the NRBS area. The results obtained from the Traditional Knowledge Survey regarding water quality perception in the NRBS area are discussed in the following paragraphs.

The overall average rating of nearby water quality by NRBS Traditional Knowledge Survey respondents was seen as somewhat negative. The average water quality rating based on a five point scale (with one being the worst and five being the best) was 2.6. This is in agreement with the concerns expressed to researchers during the Drinking Water Component interviews.

Figure 3 shows the percent of responses for perceived water quality changes observed by Traditional Knowledge Survey respondents. More than three-quarters of respondents indicated that they had noticed a change in algae growth and approximately half of those interviewed noted a change in the water insect population and turbidity.



Adapted from Summary Results From the Document "How Our Knowledge Lives" (Traditional Knowledge Component, 1995).

Figure 3. Perceived Water Quality Changes Based on NRBS Traditional Knowledge Interviews.

The Traditional Knowledge Survey also asked whether or not respondents felt that water quality had affected their health or the health of others. Fifty-two percent said that their own health had been affected, 42% indicated that their spouses health had been affected, 37% reported an affect on their children's health and 58% checked off other people's health (Traditional Knowledge, 1995). Thirty six percent of respondents did not know whether their health or anyone else's health had been affected by water quality.

As will be discussed and illustrated in subsequent sections of this report, a large percentage of people interviewed in the NRBS Traditional Knowledge Survey, utilize lake and river water for consumptive purposes. Apparantly, there are also many people that have changed their practices of using lake and river water. When asked why they stopped using lake or river water, the various reasons cited were bad taste (41%), bad smell (31%), colour (39%), disease (49%), and other reasons (28%) (Traditional Knowledge, 1995). From this, it is evident that approximatley half of the respondents that no longer use lake or river water associate some form of disease or ill-health with consuming lake or river water. The reasons stated for what made them stop were self experience (55%), media (23%), health warnings (44%), public education (21%) and other reasons (31%) (Traditional Knowledge, 1995).

3.4 DRINKING WATER TREATMENT

3.4.1 Conventional Drinking Water Treatment

There are 214 licensed drinking water treatment facilities in the NRBS area (Prince et al., 1994). The treatment processes used at these facilities vary from no treatment at all for some of the groundwater facilities to full scale conventional treatment for some of the larger facilities. There are numerous variations and types of process components used in conventional treatment facilities in the NRBS area. Generally though, conventional treatment of surface water supplies consists of coagulation, flocculation, sedimentation, filtration and disinfection steps (Drinking Water Health Effects Task Force, 1989).

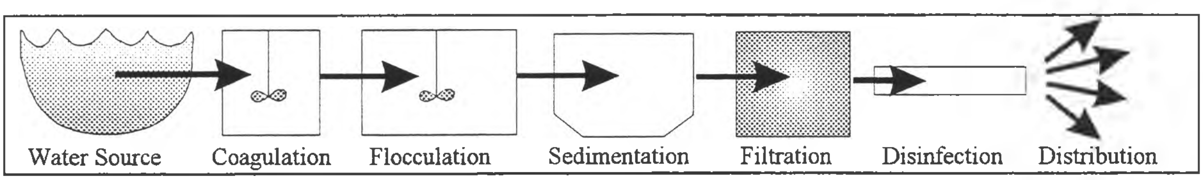


Figure 4. Typical Conventional Drinking Water Treatment Process Train

The first step in conventional water treatment is the selection of a suitable source water. This water is transported to the treatment facility where it will be treated. First, a coagulant is added and thorougly mixed so that the interparticulate forces responsible for the stability of particles are reduced or eliminated (Montgomery, 1985). Following this destabilization, less intense mixing promotes particle collisions in which aggregates of particles are formed in the flocculation step (Montgomey, 1985). Once the particle aggregates, or flocs, are formed they are left to settle out in a sedimentation basin. The next step is filtration. The water is passed through a filter medium and particulate matter either accumulates on the surface of the filter or through the depth of the filter (Montgomery, 1985). After the water is filtered, the remaining pathogenic organisms are destroyed or inactivated by a process called disinfection. Disinfection is acheived by the addition of an oxidizing chemical agent, such as chlorine, bromine, iodine, or ozone, or by using a non-chemical method of disinfection by exposing the water to ultraviolet radiation or heat (Montgomery, 1985). The final step in conventional drinking water treatment is the distribution to consumers. In the NRBS area, this may be by piped distribution systems or by trucked delivery to cisterns and water barrels.

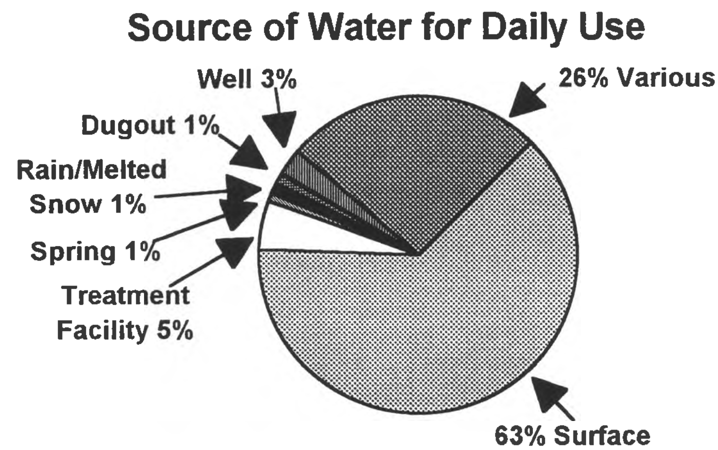
It should be noted that not all surface water supplies are treated exactly the same. The treatment processes used depend on the raw water characteristics as well as the level of treatment desired (Jacobsen, 1994). Sometimes other processes are added to the treatment sequence to combat specific contaminants and other times the source water is so good that some of the processes may be unnecessary, which is often the case with individual ground water wells. Furthermore, some treatment techniques are not financially available for smaller systems with limited resources, hence reasonable alternatives are required to ensure an adequate and safe supply of drinking water. (Drinking Water Health Effects Task Force, 1989). This is particularly the case for people living in remote locations in the Northern River Basins.

3.4.2 Non-Conventional Drinking Water Treatment

While conventional water treatment facilities are very effective systems to provide safe drinking water to people, it is not feasible to implement large scale, highly technical water treatment facilities in remote areas because these systems are not practical for small populations and are unsustainable due to high capital, maintenance and operation costs. Therefore, many people living in rural and remote areas rely on private, non-conventional, water supplies (Tobin, 1987).

There is a special population within the Northern River Basins Study area that almost certainly utilize a non-conventional source of drinking water. This population is comprised of individuals that *live off of the land*. As was found by the Traditional Knowledge Component Survey, there are many people of native descent that *live off of the land* year round (66% of those interviewed), for most of the year (18%), for half of the year (8%), and seasonally (8%) (Traditional Knowledge Component, 1995). For these people, their water is typically obtained from natural water sources in the wilderness. Therefore, people that *live off the land* are among those that utilize a non-conventional source of drinking water.

Another finding of the Traditional Knowledge Component Survey was the source of water for daily use by those interviewed. Figure 5 shows that 63% of respondents utilize surface water, such as from lakes or rivers, for daily use. Twenty-six percent of those interviewed use various sources of water for daily use and only 5% obtain their water from a water treatment facility. Although this low number of people obtaining water from a treatment plant is alarming, it must be considered that the people interviewed in the Traditional Knowledge Survey are typically elders and second-generation elders and from above, it appears that many of those interviewed *live off of the land*. However, the author of this report also suspects that many people in the NRBS area that do have access to conventionally treated water, particularly elders, may choose an alternate source of water when given the choice between conventionally treated water and some other source of water.



Adapted from Summary Results From the Document "How Our Knowledge Lives" (Traditional Knowledge Component, 1995)

Figure 5. Source of Water for Daily Use Based on NRBS Traditional Knowledge Interviews.

The map in Figure 6 illustrates the number and distribution of all people in the NRBS area that do not receive their drinking water directly (either piped or truck delivery) from conventional drinking water treatment facilities. These people rely on alternative sources of water for consumption. The top number in each box is the total population in the given area, while the bottom number is the population that receives conventionally treated water. For example, according to this map there are 14202 people living in the northwest corner of the province, yet only 5498 (39%) of these people receive their drinking water from a conventional treatment facility (served population). The other 61% or 8104 people (unserved population) must obtain their drinking water from an alternate source.

There are a few irregularities on the map that should be discussed. Since a "served" individual on this map is considered to be anyone who receives conventionally treated drinking water either through a piped distribution system or a trucked delivery system, those who haul their own water from treatment facilities will not be included in the "served population" estimates even though they drink conventionally treated water. Another anomaly is that in the more populated areas around Grande Prairie and Peace River, as well as in the southern portion of the map, the data is amalgamated into smaller regions and some crossover has occurred. Near Grande Prairie, for example, the area directly to the west of Grande Prairie shows a served rate of less than 3%. However, the served rate of the area directly east of this is 168%. Therefore, it appears that people where the served rate is less than 3% receive their drinking water from the area where the rate is 168%. The general trend that can be observed from this map is that there are many people living in the northwest corner of Alberta and other pockets throughout the NRBS area that do not have easy access to water from a conventional drinking water treatment facility. These people utilize a non-conventional source of drinking water.

In this report, "non-conventional drinking water" is considered to be a supply of drinking water other than that obtained directly from a conventional community drinking water treatment plant through a piped distribution system or from a water delivery truck. However, this definition may also extend to include water treatment plant water that has been altered in any way through further treatment such

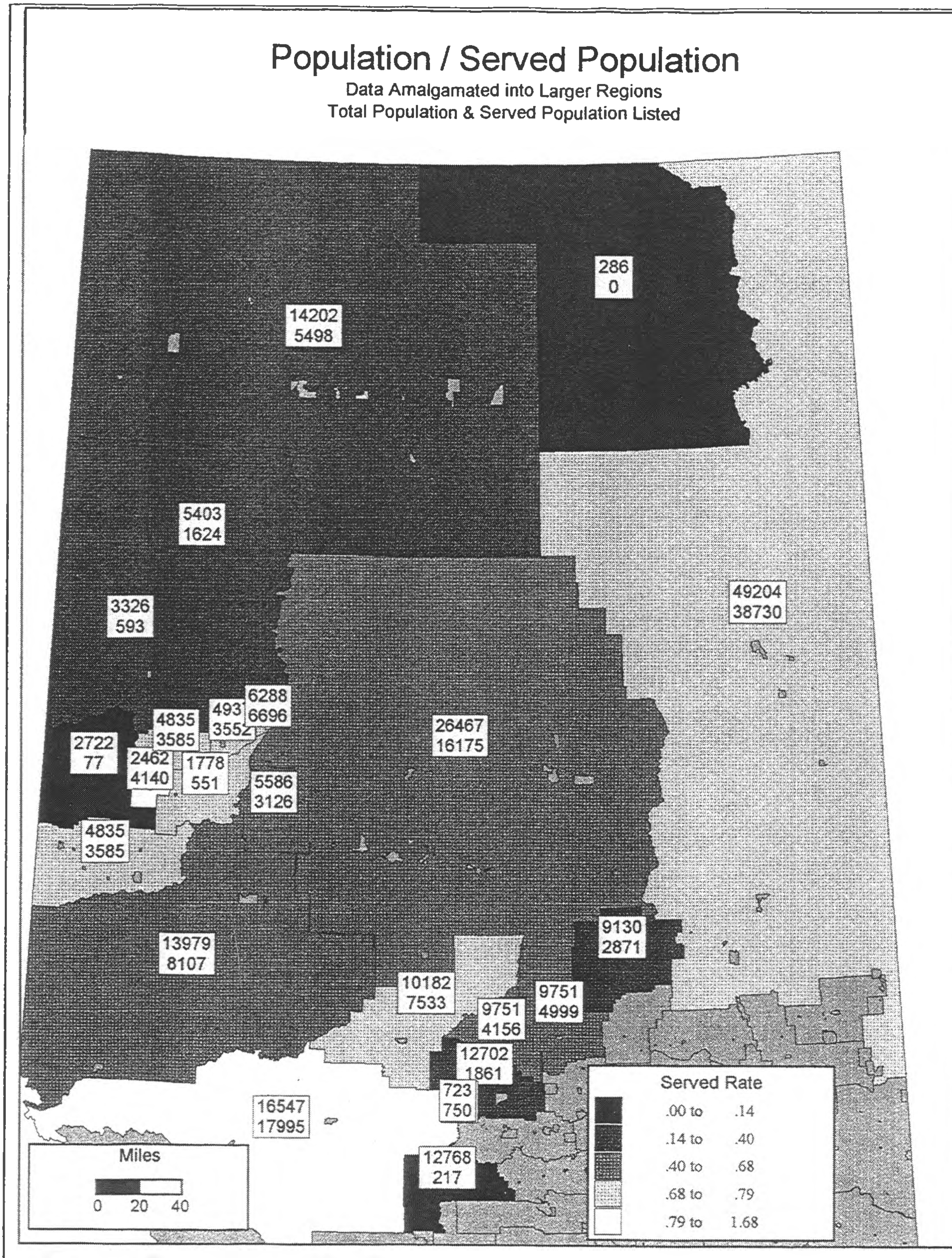


Figure 6. Conventional vs Non-Conventional Drinking Water Population in the NRBS Area

as with a point-of-use device. *Non-conventional sources* of water include surface water, rain, snow, ice, individual well water, spring water, muskeg water, bottled water, dugout water, and birch tree water. *Non-conventional drinking water treatment* would include any treatment performed on any of the above supplies other than treatment at a conventional drinking water treatment facility. Each of these sources of non-conventional drinking water and methods of non-conventional treatment utilized will be discussed in Section 3.5 of this report.

3.5 NON-CONVENTIONAL SOURCES OF DRINKING WATER IN THE NRBS AREA

3.5.1 Self Hauling of Treated Water

Aside from the large numbers of people that have their water hauled from the conventional drinking water treatment plant by a regular water delivery truck to barrels and cisterns, there are many people that haul their own water in small containers. People that rely on water delivery trucks for their water supply are considered to be serviced by conventionally treated water. The reason that 'self-haulers' are included in this discussion of non-conventional sources of drinking water is because some of the people that are not accounted for in the served population estimates of Figure 4 would obtain their drinking water in this manner. John and Lena Courtoreille from Fort Chipewyan have a cabin on Prairie River about 37km southwest of Fort Chipewyan. They use this cabin for traditional activities throughout the year such as hunting, fishing and trapping. For the past ten years, they have been hauling treated water from Fort Chipewyan in five and ten gallon containers (Courtoreille, 1994a). Hauling treated water in small containers for short "living off the land" expeditions is commonly practiced by many people. Willie Courtoreille (1994b), also from Fort Chipewyan, stated that if he goes out fishing for the day he also brings drinking water with him from town and if it is an overnight excursion, he will carry 5 gallons with him. In many cases a thermos of tea or coffee may be 'hauled' instead of plain water for day trips.

This practice of self-hauling of treated water in small containers is also practiced in non-native communities and in other parts of the province. In an interview with the Public Health Nurse from Fort Vermillion, Wendy Warden, she mentioned that she hauls her drinking water from her daughter's house in town because she feels that the well water at her house is unsatisfactory (Warden, 1994). It is apparant that there are many people in the Northern River Basin area that are burdened by tasks such as these in order to obtain a safe supply of drinking water. Self-hauling from standpipes, treatment plant, nursing station, wells and schools places a heavy burden and inconveneince on the consumer which would tend to keep water consumption low, particularly in the winter (Brockelhurst et al., 1985). Studies have shown that those who must haul water will almost never have all of the water necessary for ordinary demands and decreased quantity of water used has been implicated with poorer health (McJunkin, 1982). Another problem with hauling water in small containers is the potential for contamination. The storing of drinking water for any length of time increases the likelihood of generating large quantities of bacteria. The longer the water is stored, the poorer quality it is likely to be (Gabler, 1988). From one of the locations visited where water was being hauled in 5 and 10 gallon containers, it was sitting at room temperature and the residents would haul enough water to last them for a week at a time. In order to prevent excessive bacterial growth in water stored outside the distribution system, it is recommended to refrigerate the water and not to let it sit for more than two days before consumption (Gabler, 1988). This obviously has its limitations in situations such as these where refrigerator space is limited or non-existant, and long excursions to the treatment plant for more water every second day is impractical.

3.5.2 Surface Water

Surface water includes lakes, rivers, ponds, streams, reservoirs and any other body of water that has direct contact with the atmosphere. For the purpose of this report, rain water, snow water, and ice water are also considered surface water sources because of their direct contact with the atmosphere.

Untreated Lake, River or Creek Water

There are many people in the study area that claim that they drink the water directly from lakes, rivers and creeks. As a child, Terry Marten (1994c) and her family *lived off of the land* following the animals in the Peace-Athabasca Delta. She recalled that sometimes they would obtain their drinking water from a nearby lake or river and drink it untreated. Raymond and Yvonne Ladoucer (1994) have a cabin at Big Point on Lake Athabasca. They obtain their drinking water from Keane River which he claims is crystal clear and does not need any treatment whatsoever. He drives to a remote location on Keane River and collects 25 to 35 gallons at a time. This will generally last them 4 or 5 days.

Each year there is a pilgrimmage event at Little Red River near Fox Lake in which hundreds of people attend. Even though there is a drinking water truck at the event, many people choose to drink the water right from the river as has been done in the past (Laboucan, 1994b). One resident who was at the event in the summer of 1993, mentioned that the water from the river was "very good" even though this individual said that he had diarreah all the way home from the event. The cause of this persons diarrhea could have been the result of so many factors, but one would have to consider a waterborne illness. Yet, it should be noted that none of the other people interviewed who used untreated surface water said that they had suffered ill-health as a result of drinking untreated water.

One of the questions asked by the interviewers of the Traditional Knowledge Component of the Northern River Basins Study was what lake and river water was used for. Respondents were asked to indicate what they used lake or river water for from a list of possible responses. Ninety-eight percent of the respondents indicated that they used lake or river water for drinking and 96% of the respondents use lake or river water for making tea or coffee (Traditional Knowledge, 1995). The type of treatment, if any, performed on the water before consumption was not indicated in the report, but it is expected for those that make tea or coffee, the water would have been boiled.

Drinking untreated surface waters likely occurs in many areas in the Northern River Basins. In a telephone conversation with Elmer Ghostkeeper (1994) of Forestry Management based out of Athabasca, he said that each community is distinct but he suspects that there are certainly some people that don't treat the water at all before consumption while they are involved in traditional activities like hunting and trapping. He continued to say that most of the time people use the water to make tea or coffee which means that it will be boiled.

Brockelhurst et al., (1985) state that "self haul from lakes or creeks has all the disadvantages of handling, storage and low consumption plus the obvious problem that the water is usually contaminated at the source." It is well established that surface waters are not free from pathogenic risks. Even pristine waters (protected from human activity) have been found to contain pathogenic organisms (Rose et al., 1991). Birds and waterfowl can be a sources of fecal contamination.and *Giardia* can be carried by all types of animals. In the past, beavers were targetted as the primary animal reservoir of this microorganism, hence the colloquial version of giardiasis - Beaver Fever. However, *giardia* can be carried by many other species including muskrats, voles, coyotes and domestic animals (McFeters, 1990).

Another aspect that must be considered is that the sanitation in remote areas is generally with pit privies which are often poorly constructed and maintained. Runoff from these privies may result in the fecal contamination of nearby lakes and creeks (Brocklehurst et al., 1985). A situation like this was noted in a remote area in the Peace-Athabasca Delta. An improperly constructed outhouse allowed small animals to scatter toilet paper and human waste in the surrounding area. It is possible that this debris could have made its way into the nearby lake or could have percolated into the nearby newly constructed well. Furthermore, garbage wastes in this same location had also been haphazardly disposed of, and may have contributed significant pathogen releases to source waters.

A lack of treatment, or inadequate treatment accounted for the majority of the waterborne disease outbreaks reported in the United States in 1991 and 1992 (Moore et al., 1994). Based on the fact that there are people who claim to drink untreated water in the NRBS area, this statement can probably be applied in the Northern River Basins as well.

Rain

Rain water harvesting as a source of water for domestic consumption has been practised throughout the world for many years (Mayo and Mashauri, 1991). Apparently, the Northern River Basins Study area is no exception. Lester St. Arnault (1995) of John D'Or Prairie said that it is "quite common to see barrels around for collecting rain." Rain water is collected in 45 gallon barrels in the spring and summer months. One person who was asked about this practice in the north said that using rain as a source of drinking water is not as common as it used to be because people are afraid of the acid rain.

A 1974 USEPA document stated that precipitation in the form of rain, snow, hail, and sleet contains very few impurities. Although it may contain trace amounts of mineral matter, gases, and other substances, it has virtually no bacterial content. However, once the precipitation reaches the surface of the earth, there are many opportunities for the introduction of chemical and microbial pollutants (USEPA, 1974). A study in Tanzania assessing the quality of rainwater for consumptive purposes showed that 45% of the samples collected were contaminated with Total Coliforms, 14% with Fecal Coliforms and 53% with Fecal Streptococci (Mayo and Mashauri, 1991). The reason for this contamination was due to the improper collection and storage of the water. The quality of the collected rainwater is influenced by the quality of the precipitation, deposition on the collection surfaces and the introduction of other contaminants into the system (Mayo and Mashauri, 1991).

Due to the seasonal component associated with rainwater collection, researchers have not collected a rainwater sample from the NRBS area yet. This will be one of the tasks performed during the proposed field trip to Cadotte Lake in the spring of 1995. It will be interesting to see the extent of added contaminants to the system if two collection bottles are filled simultaneously - one directly with falling rain and one from the barrel in which the rain is usually collected. If the rain is typically more acidic than surface water, it will also be interesting to see the extent of leaching that occurs from the barrel.

Snow

In the winter time, snow is a popular source of non-conventional drinking water in the Northern River Basins, particularly for trappers. But trappers are not the only ones that melt snow for drinking water. Supposedly, one lady living near Rocky Lane in the Peace River Basin collects snow in her cistern all winter so that she will be able to drink snow water in the summer months (Bingham, 1994). Also, after a recent water main break in Atikameg, people on the piped distribution system were without treated water until the problem was solved. During this time a nurse in the area said that she thought that many people were using snow for water during this time (Schleifer, 1995).

The snow that is collected to be used for drinking water must be carefully chosen. A relatively clean area away from human activity and animal tracks is the best (Chalifoux, 1995). Of course, the cleanest possible site should be chosen. The top layer of powdery snow is swept away and the crystalline snow beneath is what is collected. Even though one would think that the top layer of powdery snow should be used because it has fallen most recently, and therefore has had less of a chance to be contaminated, this is not what is collected. The crystalline snow below has become compacted by the snow above it and the warmth of the earth below it. Therefore, it is denser and more water is obtained per volume of snow collected (Chalifoux, 1995). It is evident when this crystalline layer is reached because the collection container makes a 'scraping' sound on the cystalline snow but not on the light powdery snow. Rosie Chalifoux (1995) of Atikameg mentioned that another way to tell the difference between the powdery snow on top and the crystalline snow below is to collect it on moonlit nights because "you can see the crystals reflecting in the moonlight." In any case, once the snow is collected, it is hauled back to the site where it is to be used and it is generally melted in pots on the stove. People living off of the land may use an open fire or some other method of melting the snow before it is consumed. It is not necessarily boiled unless you are using it to make tea or coffee (Chalifoux, 1995).

Not everyone is a proponent of utilizing snow as a source of drinking water. In the pamphlet, Wilderness Water: A Guide to Wilderness Drinking Water prepared by Health and Welfare Canada and Envirnoment Canada (1991) it is recommended to use an open water source through a hole in the ice in the winter time rather than melting snow because melting snow takes extra time and uses fuel. They continued that eating snow or ice can lead to chilling and hypothermia and may cause cramps and headaches (Health and Welfare Canada and Environment Canada, 1991). Furthermore, coloured and dirty snow should not be consumed. The presence of large amounts of particulate matter may harbour bacteria and coloured snow may indicate the presence of bacteria or algae which could cause diarrhea if ingested. Certainly, there is always the possibility of contamination from animal sources as well, so only clean snow and ice should be used for consumptive purposes and regardless of the wilderness source, all water should be purified, even in the winter (Health and Welfare Canada and Environment Canada, 1991).

The snow collection season is weather dependent. Usually the little bugs that jump in the snow around the trees come out sometime in March (Chalifoux, 1995). Once these little bugs are seen, people know that the snow is not good for drinking water anymore and ice should be used instead (Chalifoux, 1995).

Ice

The winter ice cover on lakes and rivers is another source of non-conventional drinking water in the NRBS area. Saws, chisels and axes are used to cut out blocks of ice (St. Arnault, 1995; Chalifoux, 1995). Although chainsaws make this job much easier, they are not always used because they tend to leak oil and grease onto the ice and into the water (St. Arnault, 1995). Chalifoux said that the blocks taken from Utikuma Lake near Atikameg are usually about one square foot, but with some of the new equipment available, larger blocks can be made. Once the blocks are made, they are hauled out of the water using a rope and a ramp and taken to the house to be melted for water or stored to be used later (Health and Welfare Canada, 1973).

The quality of the water obtained from the ice blocks will generally be about the same as the quality of the lake or river that it covers. Since microorganisms are generally capable of surviving freezing temperatures, it should be assumed that the ice water is contaminated and appropriate precautions should be taken, such as boiling the water for tea or coffee. If ice water is used as a supply of water, once blocks are hauled to the site where they will be melted for water, the blocks should be washed so that the wash water together with the outer layer of ice is wasted. This is because the ice blocks are suseptible to considerable contamination while they are being cut and hauled. Furthermore, if two ice blocks meld together, they should be chipped apart before washing because bacteria can become trapped between the two blocks (Health and Welfare Canada, 1973).

Lester St. Arnault gave a good example of the changing quality of the ice water obtained from the Peace River. He said that people from the Little Red River Cree Band used to use ice from the Peace for their drinking water. "Now," he says, "the water you get from the ice is murky." It has sediment and it is not as clear as it used to be. In the past the ice was a bluish color before it was melted and after it was melted the water was clear. Now, the ice is cloudy, the water is dirty and people don't use it so much anymore (St. Arnault, 1995).

As mentioned above, Health and Welfare Canada and Environment Canada (1991) recommend that all sources of wilderness water should be purified before consumption. Regarding ice, once again these federal departments recommend using an open water source through a hole in the ice in the winter time rather than ice because using ice takes extra time and uses fuel Lester St. Arnault agreed with this. He said that although sometimes it is good to use ice, alot of the times it is better to make a hole in the ice instead and use the water to make tea (St. Arnault, 1994b).

Dugout Water

There are many dugouts in the Northern River Basins Study area. Dugouts are a popular source of water in rural remote areas where groundwater is of poor quality, of limited quantity, or unavailable altogether (Alberta Agriculture, 1988). Dugouts are essentially a large excavated hole in the ground that acts as a water reservoir. The Prairie Farm Rehabilitation Administration (PFRA) has a Rural Water Supply Program in place to financially and physically assist farmers in building dugouts (Gibbens, 1995). PFRA's data was compiled for dugouts in the Northern River Basins Study area and it was found that there were 5000 dugouts that are being used as a source of domestic water. This means that the dugouts provide water for all of the water needs of the home it supplies. Theoretically, this definition would include water necessary for the drinking water supply of the house. Figure 7 shows the location of these dugouts.

It should be noted that the dugouts in the figure are only those in which PFRA has been involved. It is possible that there are other dugouts in the Northern River Basins Study area that were built without the assistance of PFRA and therefore, these dugouts would not be included on this map. Also, there are some dugouts in the area that have not been categorized by use type. It is possible that some of these dugouts are also used as a source of drinking water. In any case, the numbers on the map support the thought that many of the people not receiving their water from a conventional drinking water treatment plant, obtain their drinking water from individual dugouts.

The type of treatment that is being used by these households is not available on PFRA's databases and the only way to find this information would be to survey all dugout owners which was beyond the scope of this study. The level of treatment will depend on the intended use of the dugout water. The water quality of dugouts is not officially monitored by Alberta Environment or any other agency. It is considered the responsibility of the owner to maintain the dugout and perform any necessary treatment and monitoring.

Dugout water has all of the problems associated with most surface water supplies; and then some. It is important that many factors are considered when designing a dugout including the nature of the drainage area, the soil type, areas of potential contamination, distance to point of use and daily water requirements (Alberta Agriculture, 1988). Some of the common drinking water quality problems associated with dugouts is presented in Table 2 along with possible treatment strategies.

Watering Hole Water

A watering hole is essentially a community dugout. All of the same elements are involved except that water is treated at the site (if at all) instead of in the individuals home, and water trucks are used to transport water to the point of use. There are several watering holes in the High Level area that are set up to take the demand off of the municipal drinking water treatment plant from farmers that need to water livestock. Although it is clearly marked that the water is not meant for human consumption unless boiled, an Environmental Health Officer from High Level suspects that some people may use this as their drinking water source.

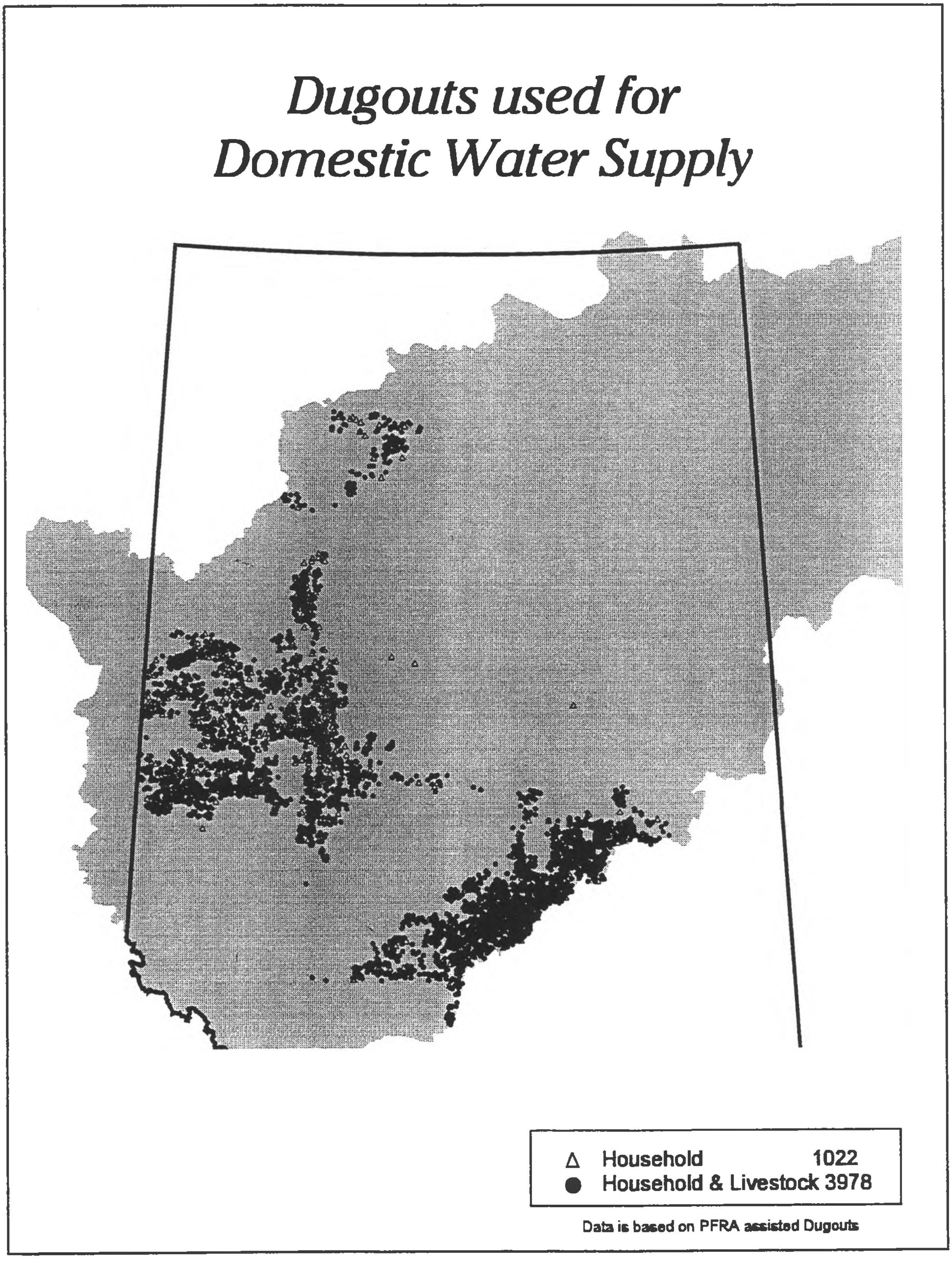


Figure 7. Dugouts Used for Domestic Water Supply

Table 2. Common Dugout Water Quality Problems and Solutions

Water Quality Problem	Cause	Treatment at Dugout	Treatment at House
Microbial Contamination	Agricultural Runoff	Use ditches and dykes to divert objectionable runoff	Filtration and Disinfection
	Domestic Sewage Contamination	Locate dugout away from domestic waste disharges	Filtration and Disinfection
	Direct contamination by animals	Put a fence around the dugout	Filtration and Disinfection
Turbidity (Suspended Material in the water)	Erosion from the watershed	Plant grass in the waterways and area around the dugout	Filtration
	Storm Runoff	Spread 10lbs of alum per 100000 gallons of water on surface. Let settle.	Filtration
Taste, Odour and Colour	Algae	Apply 1lb copper sulphate per 100 000 gallons water in spring, summer and fall.	
	Water Weeds	Apply herbicide	Do not consume for 24 hours after herbicide applied
	Decomposing Organic Material	Aerate and keep trees 100 feet from dugout edge.	
	Iron and iron bacteria		Filtration and Disinfection
Hardness	Calcium and Magnesium ions		Water Softener

(adapted from Saskatchewan Agriculture, 1983 and Alberta Agriculture, 1980)

3.5.3 Ground Water

It seems as though ground water is a favoured source of drinking water for some people living in the Northern River Basins Study area. Ground water is contained in porous spaces in rocky material below the surface and moves in areas called aquifers. The aquifer closest to the surface of the earth is called a shallow aquifer or water table while deeper aquifers are called artesian aquifers (USEPA, 1974). In order to use groundwater as a source of drinking water, it must somehow find its way to the surface. Sometimes this occurs naturally as is the case with artesian wells or springs. Other times, groundwater remains in the aquifer until the water is drawn out through a well.

Ground water has long been considered to be of unquestionable excellence, because the soil barrier acts as a protection from surface pollutants (WHO, 1993). However, it is not impossible for ground water to become polluted. There are many modes of entry of pollution into ground water supplies. These include direct injection through a well, leaching through the soil and infiltration of polluted surface water sources among others (WHO, 1993)

Well Water

In most instances, ground water wells today utilize specialized drilling equipment that has replaced the pick and shovel method of reaching the water table. But, Lesley Laboucan (1994b) said that there are still people in the Fox Lake area that live off of the land who obtain drinking water from very shallow hand dug wells. He explained that when hunters are in the wilderness, they will dig a two foot hole in the ground and wait for the water to seep up into the hole so that they can collect it to drink it (Laboucan, 1994b). Although, by definition this is a ground water well, it is a primitive one and technology today has allowed for the extraction of water from very deep and protected aquifers. Waters extracted from these "well protected aquifers are usually free from pathogenic microorganisms and the distribution of untreated groundwaters is common practice in many countries (WHO, 1993)."

Groundwater has long been considered a desirable source of domestic water. There are probably many groundwater sources in the NRBS area that meet the Canadian Drinking Water Quality Guidelines without any treatment at all. But, as mentioned above, aquifers can become contaminated and sometimes the natural levels of certain inorganic chemicals are high enough to constitute a risk to health. If ground water is used in this case, specialized treatment may be required. An example of this is a well in the Fort Vermillion area that serves about 15 people. It has been found that the well water has a nitrate concentration that exceeds the health limit set in the Guidelines for Canadian Drinking Water Quality (Bingham, 1994). The source of the contamination is uncertain but could be a result of a number of factors including sewage contamination, surface water infiltration, or leaching of nitrates from decomposing organic matter nearby. It has been suggested by the Northwestern Health Unit that the families affected invest in a reverse osmosis treatment unit which is effective at removing nitrates (Bingham, 1994). This would be a valid application of effective point-of-use technology.

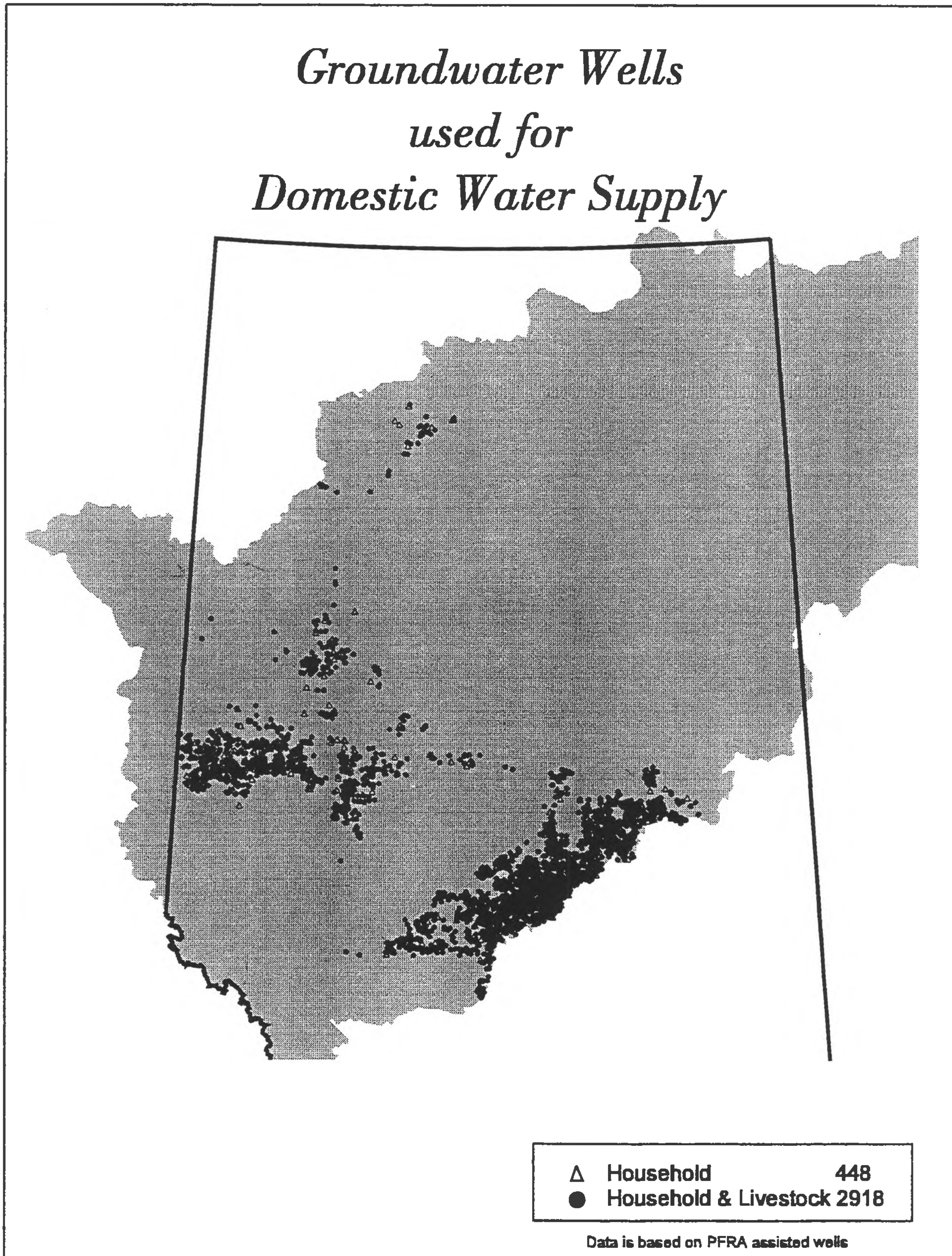


Figure 8. Groundwater Wells Used for Domestic Water Supply

Figure 8 is a map of the location of PFRA assisted groundwater wells in the NRBS area that are known to be used as a source of domestic water. As stated in the section on dugouts, domestic means that this is the water that is used to fulfill the water requirements of the home it supplies which implies that it is also used for consumptive purposes (Gibbens, 1995). According to Figure 8, there are 3409 wells that fit this description. Once again, it should be noted that the wells on this figure are wells that were drilled with the assistance of PFRA's Rural Water Supply Program. David Gibbens from PFRA said that there are likely many more wells in the NRBS area that have been drilled by other agencies. This is probably particularly true for non-farming communities because it used to be the case that in order to qualify for a grant, the applicant would have to be a "bonafide farmer" (Gibbens, 1995). This is changing though because PFRA has changed its mandate somewhat to include the needs of all rural residents, not just farmers.

If available, well water can be an excellent alternative for people that live in remote areas. A well can be located so that hauling in minimized, there is an adequate quantity available and the quality is generally very good so treatment, if any, is minimal.

Spring Water

A spring is defined as an opening in the ground surface from which ground water freely flows (USEPA, 1974). Artesian wells or springs occur where the water table comes into contact with the atmosphere or through faults in rock layers through which water from an aquifer can trickle up. There is a groundwater spring between John D'Or Prairie and Garden River that is considered sacred by local residents. Many people from John D'Or Prairie travel 37km to this spring to collect their drinking water. This particular spring resulted in a fairly large reservoir of water that collected in a nearby depression. Therefore, although this water originated from the ground, its contact with the atmosphere means that it is suseptible to contamination typical of surface waters.

It is possible to protect spring water sources by building structures to encase the supply of water coming from the spring. The main components of a spring encasement structure include a system of perforated collection pipes, a covered impermeable storage tank and a method of collecting the water. Other important features include the provision of a surface water diversion ditch, allowance for overflow from the spring and provision for cleaning and emptying the tank when necessary.

Muskeg Water

The muskeg is soft spongy moss covered ground found in many areas of the Peace, Athabasca and Slave River basins (Fraser, 1994; Chalifoux, 1995). The ground below the muskeg is saturated with water. This coupled with the fact that moss is relatively impermeable to water means that if water somehow gets on top of the muskeg, it is retained there until it slowly seeps through or until it evaporates. Sometimes, fairly large pockets of water can accumulate in the muskeg, especially after a rain event which not only contributes water directly but which also recharges the ground water thereby raising the water table.

Fred Fraser from Fort Chipewyan talked about a family camping trip every summer in which the water that they drink comes from the muskeg (Fraser, 1994). He said that they can just go and collect an cupful and drink it "straight-up", with no treatment. Some people think that muskeg water has medicinal properties. For example, Rosie Chalifoux from Atikameg said that some people in the community think that "treatment water" will clog their veins. It is thought that the cure for this clogging is to drink muskeg water which is an effective de-clogger.

Although some of the water found in the muskeg may have originated from the ground, it is essentially subject to many of the same pollutants that surface water would be. Due to its proximity to the soil and vegetation, it is likely to be laden with microorganisms in some cases. Therefore, most public health agencies would probably recommend boiling muskeg water before consumption.

3.5.4 Point-of-Use Treated Water

Treating water at the location where it is to be consumed is called point-of-use (POU) treatment. Point-of-use treatment may include treating raw water sources at the point-of-consumption or it can be the further treatment of conventionally treated water in the home.

3.5.4.1 Point-of-Use Water Treatment Processes

Boiled Surface Water

"Heat is the oldest, safest and most effective method of purifying water" (Health and Welfare Canada and Environment Canada, 1991). The boiling of water as a treatment method is a well used method throughout the world. This method works on the principal that the microorganisms present in the water supply cannot tolerate the high temperatures that are required to bring water to a boil. These high temperatures rupture bacteria cells and denature proteins so that the microorganisms die (AWWA, 1990). The amount of time that is recommended for boiling water so that water is safe for consumption varies widely in the literature as is illustrated in Table 3.

Based on this Table it is difficult to assess just how long that contaminated water should be boiled for to ensure disinfection. It appears as though every agency has its own recommendation. In the determination of guideline values of any sort, conservative safety factors are implemented to account for worst case conditions and many of the safety factors used are largely subjective. Therefore, in some cases, suggestions for public health protection may be overprotective. Furthermore, with the exception of the USEPA, none of the papers cited defined what they meant by "boil" which leaves even further uncertainty. Rice and Johnson, microbiologists from the USEPA, state that the "suggested boiling times refer to the total time that the water is held at a rolling boil and should not be confused with the first sign of bubbles being liberated in the heating process (AWWA, 1994)." Currently, Rice and Johnson are conducting an investigation requested by the Centers for Disease Control to try to resolve the issue of how long water should be boiled for to ensure adequate disinfection. The preliminary results of their study indicate that heating water to a full boil with a conservative safety factor of 1 minute is sufficient to kill cholera and 3 minutes adequately compensates for higher altitudes (AWWA, 1994).

Table 3. Effective Boiling Times cited in literature.

Reference	Boiling Instructions	Sufficient to:
Aukerman, 1989	Brought to a boil	Inactivate Giardia
Aukerman, 1989	55°C	Inactivate Giardia
Unknown (in Aukerman, 1989)	5 minutes at 64°C	Inactivate Giardia
Cerva, 1955 (in Aukerman, 1989)	Heated to 50°C	Inactivate Giardia
AWWA, 1994	Bring water to a rolling boil	Purify tap water
Dairy, Food and Environmental Sanitation Editors, 1993	Boil at 100°C for 1 minute	Kill any disease causing bacteria in the water
Fogel, 1982	Bring water to an instant boil	Kill Giardia lamblia cyst
Gabler, 1988	15minutes at 121°C	Kill bacterial spores
Tobin, 1984 (based on Geldreich and Cutrovo, USEPA and Environmental Health Directorate)	Boil for 1 minute	Kill almost all types of waterborne pathogens
Health and Welfare Canada, 1985Dispatch	Boil for 1 minute	Kill most pathogens
Health and Welfare Canada, 1985Dispatch	Boil for at least 5 minutes	Ensure disinfection
Health and Welfare Canada, 1986	Boil for several minutes (when in doubt, 5 minutes)	Kill protozoan cysts
Health and Welfare Canada, and Environment Canada, 1991	At least 15 minutes and one extra minute for every 300m above sea level.	
Health Canada Boil Water Notice, 1995	At least 10minutes	
US Department of Health Education and Welfare, 1965	Vigourous boiling for 1 full minute.	Kill any disease causing bacteria in the water.
USDA Forestry Service, 1989	1 minute boiling 3-5 minutes at high altitude	Inactivate Giardia
USEPA (Rice, E. and Johnson, C. 1994 in AWWA, 1994)	Full boil for 1 minute. Full boil for 3 minutes to compensate for lower temperatures at higher altitudes.	Kill cholera
WHO, 1993	Vigorous rolling boil for around 1 minute.	Inactivate viruses, bacteria and Giardia cysts.

Despite the low level of technology required for this treatment method, there are several drawbacks that limit its usefulness. The primary one is the requirement of fuel to heat the water. This fuel can be wood, coal or some other form. In any case, if the fuel is at a premium, then so is the availability of potable drinking water. This may be particularly relevant to people in the NRBS area that live off of the land. Building a fire is difficult if there is not an abundance of dry wood with which to make it. Furthermore, building a fire is also time consuming, as is the boiling process. Fortunately, part of this may be mitigated with the introduction of small portable gas stoves that are available on the market now. But, fuel is still a limiting factor and it still takes time to boil a batch of water regardless of the source of heat. Another drawback is that although boiling water will improve the microbiological quality of drinking water, it does not remove organic material which leaves the water susceptible to re-contamination. In addition, the aesthetic quality of the water is not improved by boiling. Colour will not be removed and often the taste is compromised. The flat taste of boiled water can be improved by aerating the water. Finally, the effectiveness of disinfection is reduced in turbid water. Therefore some agencies recommend some preliminary treatment before disinfecting. One common suggestion is to allow the particles in the water to settle out and then "filtering" the water through several layers of clean cloth (or other filter media) before disinfecting (Editors, 1993; Health and Welfare Canada and Environment Canada, 1991).

It seems as though the people that live in the Northern River Basins Study area consume large quantities of tea. One of the questions asked by the interviewers of the Traditional Knowledge Component was what lake and river water was used for. Ninety-six percent of the respondents indicated that they would use lake and river water to make tea or coffee (Traditional Knowledge Component, 1995). Herbal teas made from berries, or the stems, leaves or bark of shrubs is a traditional beverage of most native people and is still consumed today (Health and Welfare Canada, 1985). Hugh Brody (1988) also found that the people of northern B.C. would drink "cup after cup of strong sweet tea." Stella Marten of Fort Chipewyan said that when people are living off of the land that they probably drink tea 90% of the time and "to make good tea, the water needs to be boiled (Marten, 1994b)." Stella's sister, Terry remembers boiling the water at times when news of an illness in the area reached her family by word of mouth. It was also common practice to boil medicinal herbs in water if someone had the flu or diarreah (Marten, 1994c). When asked about the length of time that the water was boiled to make tea, all of the people questioned responded that as soon as the water started boiling it was ready. But this is an odd question, because in most cases people probably do not keep track of the exact amount of time that the water is boiling. In any case, boiling has proven to be a reliable treatment method for the removal of microbial pathogens and the fact that 'good tea' requires that the water is boiled should also ensure that the water/tea is safe to drink.

Chemical Addition

Chlorine

Under most conditions, chlorine compounds are suitable disinfectants of raw water. There are three chemically equivalent forms of chlorine that may be used as a disinfectant in drinking water treatment: (1) compressed gas, (2) a solution of sodium hypochlorite or, (3) solid calcium hypochlorite

(AWWA, 1990). Compressed chlorine gas is typically not used in the purification of small quantities of water for individual use. However, sodium hypochlorite solutions and calcium hypochlorite tablets are used to treat small quantities of water for drinking. When chlorine (Cl_2) is added to water (H_2O) the following reaction takes place: $Cl_2 + H_2O \leftrightarrow HOCl + H^+ + Cl^-$ (Montgomery, 1985). It is thought that hypochlorous acid (HOCl) is the agent responsible for the inactivation of bacteria and viruses by disrupting normal cell functions such as respiration and DNA activity (AWWA, 1990).

The chlorine tablets commercially available in camping and department stores are solid calcium hypochlorite. There is a new type of tablet on the market that combines the processes of chlorination and flocculation and is called a "Chlor-Floc" tablet. Both types of tablets contain the necessary dosage for drinking water disinfection and should be used according to the instructions on the label.

Household bleach is another readily available form of chlorine in the form of sodium hypochlorite. Regular household bleach contains 4 to 5¼% sodium hypochlorite. Once again there were some discrepencies in the literature regarding the effective dose of chlorine bleach in the disinfection of drinking water. For the most part, it was recommended that 2 drops (0.1mL) of bleach be added per liter of water, mixed thoroughly by stirring or shaking, and allowed to stand for 30 minutes before consumption (WHO, 1993; Editors, 1993). If the water is turbid or if a slight chlorine odour is not detectable after this time, the treatment should be repeated or the initial dosage doubled (Health and Welfare Canada and Environment Canada, 1991; Tobin, 1987).

The disinfection effectiveness of this recommended chlorine dose and reaction time can be assessed with the help of CT values. A CT value is a measure of disinfection capability, where "C" is the residual disinfectant concentration in mg/L and "T" is the related contact time in minutes (Process Development Team, 1991). The USEPA has compiled several tables of CT values based on the evaluation of existing laboratory data on disinfection efficiency (USEPA, 1991). Adapted tables from this USEPA document of CT values for *Giardia* and virus inactivation have been included for both free chlorine disinfection (Table 4 and 5) and for chloramine disinfection (Table 6 and 7). By examining these tables it is evident that disinfection is compromised at lower temperatures as witnessed by the higher CT values at colder temperatures. Furthermore, for *Giardia* inactivation by free chlorine in Table 4, it appears as though the higher the pH, the higher the CT value. Tables 6 and 7 list the CT values for chloramines. If ammonia is present in a water supply, as is the case in some of the water samples taken in the NRBS area, then the disinfectant can be thought to have similar disinfection capabilities as in the chloramine tables. When discussing microbial inactivation by disinfection, "log removals" are more convenient to work with than "percentage removals." Log inactivation and percentage inactivation have the following relationship:

$$\boxed{y = 100 - (100/10^x)}$$

where, y = log inactivation and, x = percent inactivation (Process Development Team, 1991). Therefore a 1 log reduction is equivalent to a 90% removal, a 2 log reduction is the same as a 99% removal and a three log inactivation is equal to a 99.9% inactivation and so on.

Table 4. CT Values for Inactivation of Giardia Cysts by Free Chlorine.

Inactivation	0.5 °C			20°C		
	pH 7	pH 8	pH 9	pH 7	pH 8	pH 9
1.0 log	79	115	167	21	30	44
2.0 log	157	231	333	41	61	88
3.0 log	236	346	500	62	91	132

(adapted from USEPA, 1991)

Table 5. CT Values for Inactivation of Viruses by Free Chlorine.

Inactivation	0.5°C		20°C	
	pH 6 to 9	pH 10	pH 6 to 9	pH10
2.0 log	6	45	1	11
3.0 log	9	66	2	16
4.0 log	12	90	3	22

(adapted from USEPA, 1991)

Table 6. CT Values for Inactivation of Giardia by Chloramine.

Inactivation	≤1°C	20°C
	pH 6 to 9	pH 6 to 9
1.0 log	1270	370
2.0 log	2535	735
3.0 log	3800	1100

(adapted from USEPA, 1991)

Table 7. CT Values for Inactivation of Viruses by Chloramine.

Inactivation	≤1°C	20°C
2.0 log	1243	321
3.0 log	2063	534
4.0 log	2883	746

(adapted from USEPA, 1991)

To illustrate the applicability of these tables in the determination of appropriate reaction times for disinfecting a given volume of water with household bleach, several examples will be worked through. First, preliminary calculations of the chlorine concentration in regular household bleach was found to be 52500mg/L. Therefore, when 0.1mL of this concentration is added to 1L of water, the initial free chlorine concentration in the water sample is 5.25mg/L. For the purpose of the following examples, it will be assumed that the desired residual chlorine concentration is to be 2.0mg/L (i.e. the value for "C").

Example 1:	Target of 2 log reduction of *Giardia* Volume of water to be treated = 1L Temperature of water = 0.5°C pH = 8 Ammonia is not present in the water.
Solution:	The CT value of 231mg/L·min is obtained from Table 4. Therefore, (2.0mg/L) · T = (231mg/L·min) and T = (231mg/L·min)/(2.0mg/L) = 115.5 minutes. This is almost four times the recommended reaction time of 30 minutes as suggested in the literature.

Example 2:	Target of 2 log reduction of *Giardia* Volume of water to be treated = 1L Temperature of water = 20°C pH = 8 Ammonia is not present in the water.
Solution:	The CT value of 61 mg/L·min is obtained from Table 4. Therefore, (2.0mg/L) · T = (61 mg/L·min) and T = (61mg/L·min)/(2.0mg/L) = 30.5 minutes. This corresponds to the 30 minute reaction time that is recommended in the literature for disinfecting water with bleach.

Example 3:	Target of 4 log reduction of viruses Volume of water to be treated = 1L Temperature of the water = 20°C Ammonia is not present in the water.
Solution:	The CT value of 3 mg/L·min is obtained from Table 5 for a pH of 6 to 9. Therefore, (2.0mg/L) · T = (3mg/L·min) and T = (3 mg/L·min)/(2.0mg/L) = 1.5 minutes. This is far less than the reaction time of 30 minutes suggested in the literature.

Example 4:	Target of 4 log reduction of viruses Volume of water to be treated = 1L Temperature of the water = 20°C Ammonia is present in the water.
Solution:	The CT value of 746 mg/L·min is obtained from Table 7. Therefore, (2.0mg/L) · T = (746 mg/L·min) and T = (746 mg/L·min)/(2.0mg/L) = 373 minutes. This reaction time is more than 6 hours.

From these examples it is evident that temperature, pH and the presence of ammonia are important considerations when determining appropriate reaction times for disinfecting water with chlorine. Therefore, although a reaction time of 30 minutes will be adequate for a 2 log *Giardia* inactivation and a 4 log virus inactivation at a pH of 8 and a temperature of 20°C, lower temperatures and the presence of ammonia will necessitate an increase in reaction time.

There are also other drawbacks to this method of purification. Many people find the taste and odour associated with the disinfection of water with chlorine unappealing. This chemical taste can be masked by adding flavoured drink crystals after the treatment time has elapsed. Another problem with the addition of chlorine to water is the formation of potentially carcinogenic disinfection-by-products. Organic matter in the water acts as precursors for these by-products of chlorination. An additional problem with this type of treatment is that chlorine loses its effectiveness with age and exposure to air, sunlight and heat (Health and Welfare Canada and Environment Canada, 1991). Nonetheless, if properly used, chlorine is an effective disinfectant.

Iodine

Iodine is another chemical that has proven to be an effective disinfectant over the years. Several forms of iodine can be used as a disinfectant including tincture of iodine, iodine tablets, and iodine crystals. Iodine tablets are readily available in camping and department stores and should be used according to the manufacturers directions. Iodine crystals, also available through camping stores are somewhat more complicated. Four to eight grams of crystals should be added to 30mL of water in a glass bottle and shaken for one minute. After the crystals have settled, approximately 15mL of this solution should be added per liter of untreated water. Since the iodine crystals are toxic, they should not be allowed to be transferred to the drinking container. The remaining crystals can be used in the same manner until they are no longer visible in the bottom of the glass bottle. For optimum iodine disinfection, the bottle should be kept warm around body temperature (Health and Welfare Canada and Environment Canada, 1991).

A 2% tincture of iodine commonly found in medicine cabinets can be used to purify untreated water. Once again, various recommended contact times and disinfectant dosages were found in the literature. Health and Welfare Canada and Environment Canada (1991) say that 8 to 10 drops (0.4 to 0.5mL) of a 2% tincture will purify 1L of untreated water. Tobin (1984) and the Editors (1993) recommend approximately 5 drops (ca 0.25mL) of a 2% tincture. Tobin adds that the solution should be well mixed and allowed to stand for 30 minutes.

Disinfection with iodine has some problems. First of all, effectiveness of iodine decreases with colder temperatures and turbid waters. Therefore, higher doses and longer contact times are recommended in these situations. Second, the taste of iodine is not particularly pleasant, but as with chlorine, this can be remediated with flavoured drink crystals. And finally, although iodine is an effective disinfectant for emergency and short term sources of drinking water, it is not recommended that iodine be used for more than three weeks per season. Furthermore, children, pregnant women and people with thyroid problems should avoid using iodine all together due to potential adverse health effects (Health and Welfare Canada and Environment Canada, 1991).

Simple Treatment for Volatile Organics Removal

Many people living in the Northern River Basins Study area find the taste and odour of chlorine ("Perfex" or "Javex") in their drinking water displeasing. In one of the households visited, the occupants aerated the water overnight so that some of this chlorine would dissipate. They did this by collecting about two liters of water in a plastic container and letting it sit on the counter overnight before consumption. Although this is an effective method of removing volatile organics and chlorine, ideally water should be consumed immediately after treatment to prevent deterioration (Gabler, 1988). This is because some types of microorganisms can grow in almost any water, especially at warm temperatures (Health and Welfare Canada, 1985b).

The USEPA identified simple and effective methods of removing volatile organics from drinking water using materials found in the common kitchen (Gabler, 1988). The methods studied included boiling, electric mixing, pouring, open standing and various other forms of aeration. Electric mixing for ten minutes was very effective at removing more than 95% of the volatile organics in the water. Other aeration techniques investigated including open standing of the water for at least 48hours, pouring water back and forth between two containers twenty times and aeration of water using a device that aerates a fish tank. The open standing method was found to remove 95-98% of the chemicals, but this method has its limitations (Gabler, 1988). Leaving the water stand for such a length of time will certainly foster bacterial proliferation. Also, waiting two to three days for a glass of water may not always be practicable. The other aeration methods were not particularly effective.

Boiling is very effective at removing volatile organic chemicals from conventionally treated drinking water. The reason for this is that the boiling points for volatile organics are generally much less than for water. Therefore, by heating the water, the volatile organics will reach their boiling points and enter the gaseous phase, thereby being removed from the water. USEPA researchers found that all of the volatile organic chemicals added to their test water were removed after 10 minutes at a rolling boil (Gabler, 1988). Aside from the beneficial effects of organics removal by boiling, boiling the water for this length of time will also effectively kill the microorganisms present.

Although the chemical disinfection methods and other simple processes just described may be appropriate for emergency situations or for short living-off-the-land excursions, there are other alternatives that may be more efficient for purifying drinking water on a continual basis. This may include the installation of a point-of-use device in the home. Such a system should employ as many processes as technically and financially possible. A multi-barrier approach will provide the highest quality water.

3.5.4.2 Point-of-Use Water Treatment Devices

The utilization of Point-of-Use treatment devices for supplying a safe supply of drinking water has been gaining popularity. "Point-of-use devices are treatment systems installed on single or multiple taps and are intended to treat water for drinking and cooking only (Health and Welfare Canada, 1991a)." According to the Canadian Water Quality Association, the sale of point-of-use drinking water treatment devices is a 700 million dollar a year industry in Canada (Robertson, 1995).

Currently there is no specific legislation in place governing point-of-use drinking water treatment devices (Robertson, 1995). Health Canada is working on the Drinking Water Safety Act which will include legislation for these devices.

Home treatment devices employ a variety of basic processes such as filtration, adsorption, ion exchange, reverse osmosis and disinfection. Different units are designed for different water quality problems. Some of the more sophistocated treatment units intended for individual homes are called package plants. These are essentially miniature conventional drinking water treatment plants that use a multi-barrier approach to water treatment. Generally, water treatment processes can be divided into those that disinfect by killing microorganisms and those that physically remove contaminants in the water supply. The different types of units available on the market will be discussed under these two headings.

Disinfection Units

"Disinfection is the one step in water treatment specifically designed to destroy pathogenic organisms and thereby prevent waterborne diseases, which are the most common health risks associated with drinking water (Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1993)." Some of the common disinfection methods used are the addition of oxidizing chemicals, applying heat and exposing the water supply to ultraviolet radiation.

Chlorinators

The use of chlorine with municipally treated water systems has virtually eliminated waterborne microbial diseases, due to chlorine's ability to kill or inactivate essentially all enteric pathogenic microorganisms (Health and Welfare Canada, 1991a). Water can be treated at the point-of-use with liquid sodium hypochlorite or solid calcium hypochlorite. As discussed above, hypochlorous acid generated from the addition of chlorine to water, inactivates bacteria and viruses by disrupting normal cell functions and DNA activity (AWWA, 1990).

Besides its effectiveness at inactivating microorganisms in the water, chlorine is also a suitable agent for the removal of iron and sulphur from well water (Health and Welfare Canada, 1991a). Therefore, when point-of-use chlorinators are used to remove iron and sulphur the consumers also have the added protection from microorganisms.

Ozonators

Ozone is an unstable form of oxygen that consists of three oxygen atoms (Jacobsen, 1994). Ozone is a powerful oxidizing agent that disinfects by stripping electrons from molecules. Ozone has been called the most powerful disinfection agent known (Burris, 1986; Pontius, 1994). But, Montgomery (1985) points out that other factors besides oxidation potential such as cell permeability, and germicidal properties must also be considered. Ozonation is dependent on good mixing of ozone with the water and has a very short lived residual disinfectant. Researchers have hypothesized that the mechanism of inactivation by ozone is by damaging the genetic material of the microorganisms (AWWA, 1990).

For household applications, ozone is effective at eliminating taste and odour causing organics. Ozone is unstable and must be generated on site. Household type ozonators consist of a large box that has a hose emanating from it that bubbles ozone into a container of water (Tobin, 1987). These units require electricity and a large amount of space to house the apparatus (Health and Welfare Canada, 1985b).

Ultraviolet Radiation Units

Ultraviolet (UV) light is described as radiation with a wavelength between 180nm to 400nm (Gabler, 1988). This is a shorter wavelength than visible light and therefore carries more energy (Gabler, 1988). The mode of action in ultraviolet disinfection units is by the inactivation of the microorganism's DNA.

One type of home UV unit includes a mercury vapour lamp that emits UV light with a wavelength of 253.7nm (Gabler,1988). This mercury vapour lamp is housed inside a cylindrical quartz sleeve and the water to be treated flows around the sleeve. UV disinfection has its disadvantages. First, turbidity in the water limits the effectiveness of UV disinfection (Cullotta, 1989). Second, UV does not kill the spores of giardia and cryptosporidium (Jacobsen, 1994). Third, ultraviolet units require electricity and the equipment requires significant supervision and maintenance (Cullotta, 1989).

Distillers

Distillation is a process whereby water is heated in a flask, and hot water vapor rises into a tube through a series of baffles into a collection chamber where the steam condenses and changes back to the liquid form (Gabler, 1988). This type of treatment is effective at reducing dissolved solids, metals, minerals and particles because they remain in the boiling water (Cullotta, 1989). Furthermore, boiling the water will effectively kill microorganisms. Distillers have their drawbacks. For example, if the untreated water contains chemicals with a lower boiling point than water (such as pesticides, chloroform, benzene, toluene and xylene), these chemicals will also boil off with water and become concentrated in the treated water (Lester and Lipsett, 1988).

<u>Mechanical Removal Units</u>

Filters

Filtration is a water treatment process used to remove suspended particulates such as clay, silt, microorganisms and other organics (AWWA, 1990). Removal efficiency depends on the quality of the water supply, as well as the type of filter material being used. There are many types of filter media such as spirally wound fibers, string, acrylic filaments, ceramic, sand, pleated paper, pleated non-woven fabric and membrane material with pre-determined pore sizes.

There are two classes of filters: depth filters and screen filters. Depth filters consist of an array of fibrous, granular or sintered material that is pressed, wound or bonded together and particles are trapped throughout the whole depth of the filter (Gabler, 1988). In depth filters suspended particles are removed by any number of several processes including:

1. Being strained through the pores in the filter bed
2. Adsorption of the particles to the filter grains
3. Settling of the particles while in media pores
4. Floc growth while travelling through the pores and,
5. Sometimes biological mechanisms (Jacobsen, 1994; Troyan and Hansen, 1989)

Currently, there are a wide variety of portable water filtration units on the market that utilize the depth filtration concept. The filter media ranges from activated carbon, polyethylene, ceramic, iodinated resins, silver impregnated ceramic, and paper filters. The filters are typically hand held units that are pumped to force the water through the media. The filter media fits into the casing of the units and the cartridges can be replaced when the media is exhausted. These devices have been designed with the wilderness camper in mind and therefore may be applicable to northern people that live off of the land. Although researchers did not identify anyone using such a device in the NRBS area during the course of this study, they decided to pursue the effectiveness of a representative sample of some of the units on the market through some rigorous lab testing to see if they would be a viable alternative. Basically, it was found that none of the filters lived up to all of the manufacturers claims. Two of the three units tested were totally ineffective at removing bacteria in the first liter of water filtered. The results of this testing are presented in Section 3.8 of this report.

Screen filters retain all particles larger than its pore size on the upstream surface of the filter. An example of a screen type or membrane filter being used in the Northern River Basins is cloth. Terry Marten from Fort Chipewyan remembers when her mother would use a fabric bag to strain the dirt out of the water before consumption. Apparently, pouring water through a clean cloth to obtain drinking water from raw water sources is still being practiced by people in the Northern River Basins area (Marten, 1994c; Ghostkeeper, 1994; Chalifoux, 1995). Large particles in the water are removed when water is strained through a piece of clean cloth. The size of the mesh is the controlling factor in this method and the smaller the weave, the better. It is important that the cloth used is durable, kept clean and used only for water filtration. Tightly woven cloth can be used by covering the opening of a water jar and pouring the water through the cloth into another collection jar. This method will remove some of the larger suspended particles in the water. There are also membrane filter papers available that have a pore size of 0.2 microns. With this small pore size, these filter papers are capable of retaining all bacteria (Gabler, 1988). Due to the small particle retention surface of these screen type filters, they clog rapidly. Furthermore, they are expensive (Gabler, 1988).

Adsorption Units

Adsorption is the accumulation of a substance at the interface between two phases, such as a liquid and a solid (AWWA, 1990). Activated carbon is an effective adsorbent. Activated carbon can be made from a variety of substances including animal bone, coconut shells, wood or coal. The carbon is heated to extreme temperatures in the presense of steam and absence of oxygen so that miniscule pores within the material are formed, thereby increasing the surface area for adsorption and particulate entrapment (Geldreich and Reasoner, 1990). Activated carbon comes in three forms; Granular Activated Carbon (GAC), Powdered Activated Carbon (PAC) and a compressed activated carbon cake. Both granular and block carbon are preferred over the powdered kind because the powdered carbon is prone to releasing carbon particles into the cleaned water (Lester and Lipsett, 1988). The pressed carbon cake has an advantage over GAC because it avoid problems of channel formation that occurs with granular media (Geldreich and Reasoner, 1990).

The extent that activated carbon point-of-use devices are being used in the Northern River Basins Study area is unknown. It is known however, that some people do use them on the chlorinated treated water. Researchers were told of a home in which a carbon unit was mounted directly onto the drinking water tap. Another household in the same area was utilizing a portable pour-through system that treated one cupful at a time. The owner of this unit said that she was using it to get rid of the chlorine in the drinking water. Activated carbon units are effective at removing organic chemicals, taste and odour causing compounds and chemical compounds produced by microorganisms (Lester and Lipsett, 1988). But, they are not effective at removing heavy metals, nitrates, dissolved iron or bacteria. In fact, using activated carbon devices may lead to the deterioration of the microbiological quality of the treated water. Bacterial colonization of activated carbon point-of-use devices has been well documented (Gabler, 1988; Geldreich et al., 1985; Reasoner et al., 1987; Regunathan and Beauman, 1987). Furthermore, once the carbon is exhausted, there is a potential for the collected contaminants (microbial and organic) to be sheared off and released from the filter beds leading to an increase in these contaminant levels in the finished water (Lester and Lipsett, 1988; Geldreich and Reasoner, 1990). It is for this reason that "Health and Welfare Canada insists that activated carbon filters and related packaging, promotional and instructional materials be clearly labelled "Use only on municipally treated water or other supply known to be microbiologically safe" (Health and Welfare Canada, 1991b)"

Ion Exchange Units

Ion exchange is a process in which ions in solution are exchanged with ions of like charge located on the surface of the solid being contacted (Montgomery, 1985). Home water softeners work on the principal of ion exchange. They are primarily used to remove hardness from water, which in most natural water is made up of calcium and magnesium ions. Essentially, water containing calcium and magnesium ions is passed through a column filled with resin beads that have sodium ions attached to the internal and external surfaces. When the hard water passes these resin beads, magnesium and calcium ions are exchanged for sodium ions, so the magnesium and calcium is removed in the treated water (Geldreich and Reasoner, 1990).

Although the use of ion exchange units is widespread in the removal of hardness, ion exchange units are also effective at removing other types of contaminants as well. Cationic softeners exchange sodium and potassium ions for calcium, magnesium, iron and manganese ions. Anionic softeners exchange hydroxl ions for sulfates, nitrates, bicarbonates and chlorides (Culotta, 1989).

Reverse Osmosis Systems

Reverse Osmosis (RO) involves applying a pressure differential across a semi-permeable membrane so that dissolved ions, molecules and solids, cannot pass through, but water can (Geldreich and Reasoner, 1990). Rozelle (1987) explains that most RO systems placed at the point-of-use in a house utilize several processes in order to be most effective. First, the water passes through a particulate filter to remove larger particles. Second, the water passes through an optional activated carbon filter. This filter is placed on-line for chlorinated water supplies to remove chlorine because many of the RO membranes are chlorine-sensitive. Third, water is forced through an RO module which is a water reservoir containing a pressurized rubber bladder. The most common types of semi-permeable membranes used in RO systems are cellulose acetate and polyamide (Rozelle, 1987). Finally, the water may pass through another optional activated carbon filter before it is delivered to the point of consumption. Although RO units are very effective at removing heavy metals, total dissolved solids, nitrates, asbestos and *Giardia* cysts, the membranes are not effective at removing small organic molecules. Also, the membrane must be properly cared for. It can be broken down by microbial degradation or excessive water pressure. (Geldreich and Reasoner, 1990)

Without an in-depth analysis of all homes in the Northern River Basins Study area it is difficult to assess which types of point-of-use units and processes are being utilized in the study area. It is likely that many of the people living in remote rural areas may be using some of these types of systems. And it is possible that many of the people that receive their drinking water from a conventional treatment facility further treat their water with a point-of-use device before they drink it.

3.5.5 Purchased Bottled Water

Although it is difficult to assess the utilization of bottled water in the Northern River Basins on an individual basis, it is definately available to consumers there. During field trips during the course of this study, all of the stores visited had a selection of bottled waters in their fridges. Some people in the NRBS area are so worried about the quality of their drinking water that they turn to purchasing bottled water. For instance, as previously stated, one mother from Fort Chipewyan was afraid of the health effects that conventionally treated water would have on her baby. Therefore, she went to the expense and trouble of purchasing special bottled water for him all the way from Fort McMurray. This is probably not an isolated case.

The sales of bottled water has been increasing in Canada over the past few years. It has been hypothesized that the the sale of bottled water has skyrocketed anywhere where the public suspects that the local water supply is contaminated (Gabler, 1988). Since the price of bottled water is 500 to 1000 times more expensive to buy than tap water, selling bottled water has become a profitable business. As Gabler (1988) and the Editors of Consumer Reports Books explain, there are many types of bottled water on the market today:

1. *Still water* is any bottled water that is not carbonated. It can be natural or it can be treated.
2. *Sparkling water* is carbonated with carbon dioxide.

3. *Spring water* comes from a ground water spring. Spring water can be naturally carbonated or carbon dioxide may have been added by the bottler. The word "natural" in the product name means that the water has not been processed in any way.
4. *USP purified water* is pharmaceutical grade water that meets the standards of the United States Pharmacopoeia.
5. *Mineral Water* is water that contains a certain concentration of dissolved salts. Sources of mineral water can be spring, still, drinking or purified water. The salts can either be those present in the original water source or they may have been added.
6. *Distilled Water* is any type of water that has been distilled.
7. *Bottled drinking water* implies nothing about the source. It can be from a spring, a well, a lake, a river or a household tap and it may have been processed in some way. It is basically water in a bottle.

Although in some instances, bottled water may have been marketed as the epitomy of healthy drinking water, this is not necessarily the case. The general bacterial counts of some bottled waters can be particularly high. And, the longer that the bottled water sits, the higher the bacterial count becomes (Gabler, 1988). Carbonated brands may not have counts as high as uncarbonated varieties because carbonation lowers the pH which is effective at killing some strains of bacteria (Gabler, 1988). Bacteria is not the only problem though. Organics can enter bottled water in several ways. First, the raw water source used for the bottled water may contain organics. Second,organics can somehow inadvertantly be added by the bottler. An example would be by bottlers that use chlorine in their disinfection process, thereby producing chloroform as a by-product. Third, organics in bottled water can be leached from the bottle itself. Most bottled water comes in plastic bottles. "Among the organics that leach from plastic bottles are plasticizers used to keep the bottle flexible, mold-release compounds used to get the bottle out of the mold when it is made, and unreacted plastic material itself (Gabler, 1988)."

In addition to the high general bacterial counts and the potential organic problem in bottled waters, there have also been reports of excessive mineral levels in some brands. For the most part, the inorganic mineral content in bottled water is generally low. However, some brands of mineral water may not meet inorganic chemical standards, with sodium notable in the group (Gabler, 1988). Also, in 1987, Consumer Reports tested bottled waters and found that four of the mineral waters exceeded United States arsenic and flouride standards. Based on this, Gabler and the editors of Consumer Reports Books (1988) recommend that mineral water should be used in moderation and "children should generally not be given mineral water."

3.5.6 Other Sources of Water

A traditional source of drinking water is available every spring in some areas. In April and May, birch trees are tapped for "really good drinking water (St. Arnault, 1994a)." A 1cm deep and 2 inches long incision is cut on a slant on the bark of a fairly large diameter birch tree. A twig is placed in this incision to act as a tap so that the water can drip into a bucket below. The next morning about 3 gallons of the Birch-water is collected (St. Arnault, 1994a). The water is sweet tasting and can be made into molasses (Bill, 1994). Other trees such as the poplar can also be used, but the water from the poplar is much foamier. After the water is collected, the incision is sealed back up with spruce gum so that the tree does not get an infection. The following year, a different tree is used so that the tree does not become stressed and die (St. Arnault, 1994a).

3.6 SAMPLING SITES

Figures 9 to 11 show where non-conventional drinking water samples were taken in the Northern River Basins during the course of this study. The sampling spots were chosen with the guidance of residents in the area based on where people obtained drinking water outside of the conventional drinking water treatment plant Fred "Jumbo" Fraser assisted researchers in collecting 6 samples in the Peace-Athabasca Delta on September 27 and September 28, 1994. Access to the remote areas visited in this area was with Jumbo's powerboat. On November 1 and November 4, in the John D'Or Prairie area, water samples were collected with the assistance and guidance of Lester St. Arnault. Lea Bill, one of the NRBS Traditional Knowledge Component Leaders, was also involved in sampling in both the John D'Or and Fox Lake areas. Lesley Laboucan acted as the resident non-conventional drinking water sampling guide in Fox Lake on November 2, 1994. And in Atikameg, one of the CHR's (Community Health Representative) Rosie Chalifoux, helped researchers collect potable water and potentially potable snow in the area. This sampling was done on February 28, 1995.

3.7 ANALYSIS OF WATER SAMPLES

3.7.1 Sampling Protocol

All samples were collected and analyzed as set out in Standard Methods for the Examination of Water and Wastewater (American Public Health Association et al., 1992). Once the samples were collected, they were analyzed for several physical, chemical and microbiological parameters. Some of this analysis was done in the field at the site of collection and some of the tests were analyzed in a laboratory setting. The parameters that were analyzed in the field were turbidity, temperature, pH, conductivity, free and total chlorine (if applicable), ammonia, odour and colour. Turbidity was measured with a portable Hach turbidimeter that was calibrated with prepared formazin suspensions. A pH meter was used for the pH measurements and the rest of the field analyses were performed with a portable Hach Drel/5 Spectrophotometer.

The other tests performed on the samples were metals analysis, total organic carbon determination trihalomethane formation potential analysis and microorganism assays. All of these were performed in the lab. Since microbial analyses must be performed on samples within 24 hours of being collected, samples were couriered back to the University of Alberta Environmental Engineering Lab for analysis immediately after being collected. Total Organic Carbon was also determined at the University lab

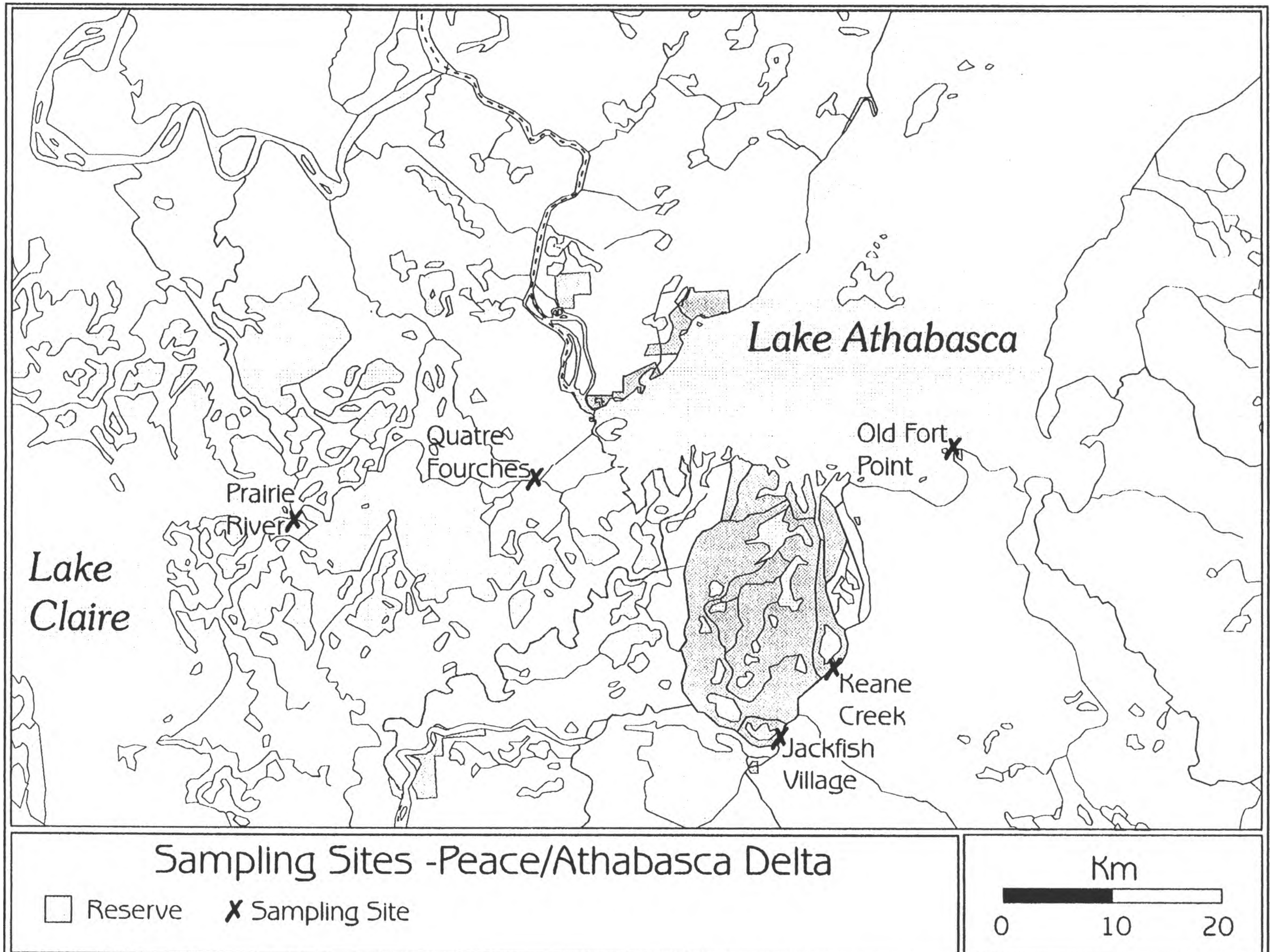


Figure 9. Peace-Athabasca Delta Sampling Sites

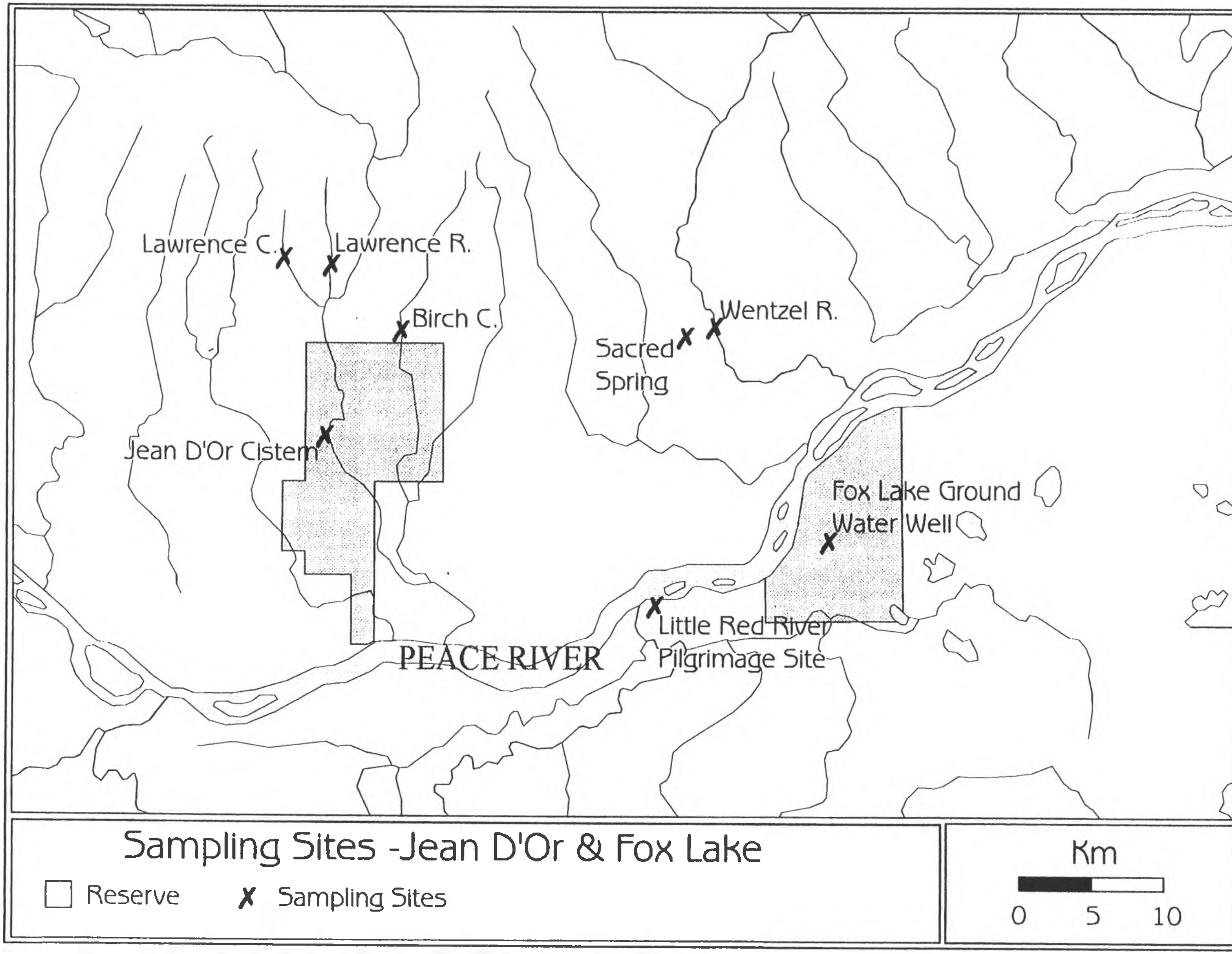


Figure 10. John D'Or Prairie and Fox Lake Sampling Sites

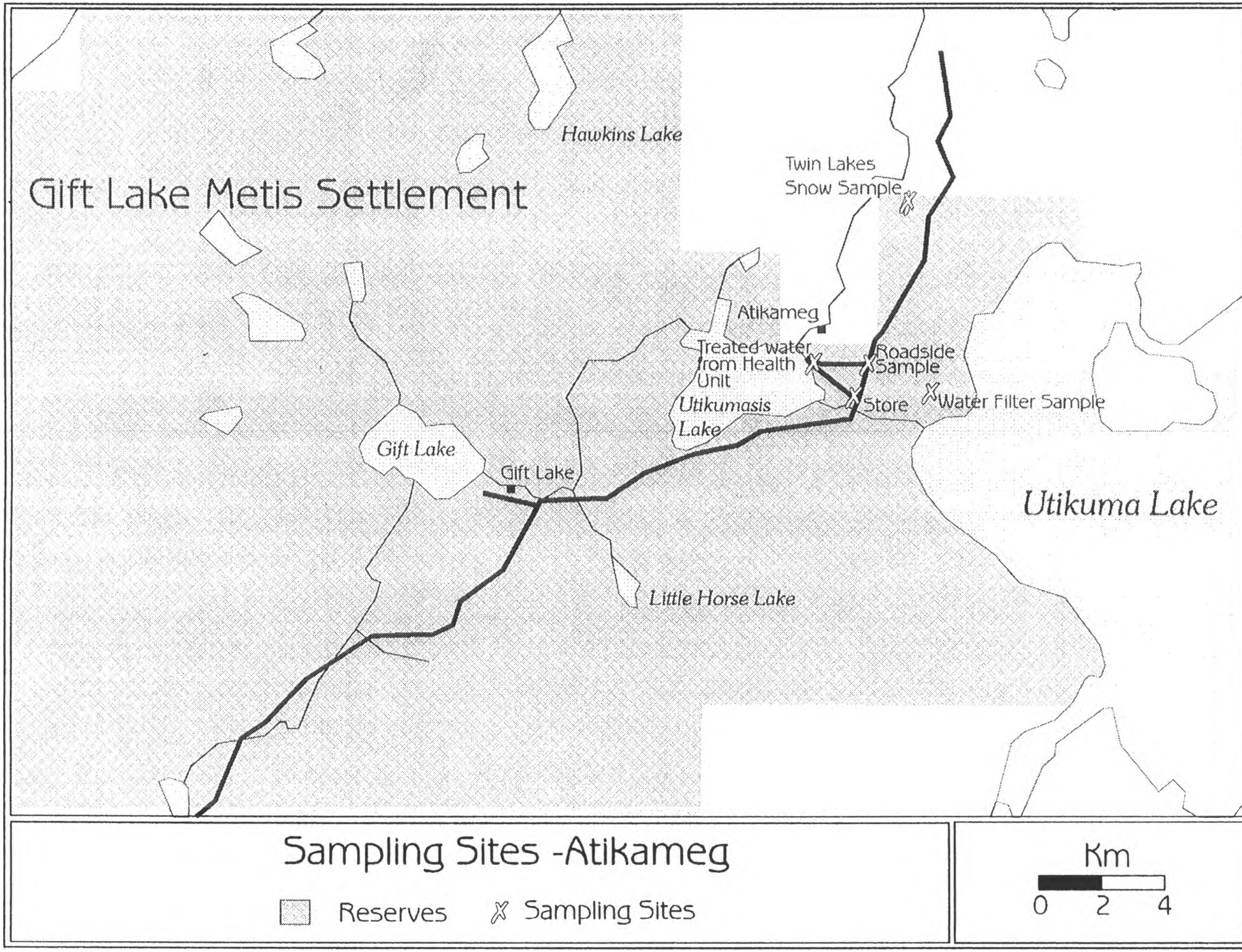


Figure 11. Atikameg Sampling Sites

for each sample. Acidified samples were sent to the Analytical Lab at Sherritt Inc. in Fort Saskatchewan where they were analyzed for heavy metals by Atomic Absorption.

Most of the physical and chemical parameters that were analyzed in the field are routine parameters that give a general description of the composite water sample and those that affect the aesthetic appeal of the water for drinking. In addition, these are the same phys-chem parameters that were tested by other members of the Drinking Water Component during site visits to conventional drinking water treatment facilities in the NRBS area (Prince et al., 1995). The metals selected for analysis were chosen based on all of the heavy metals that are regulated in the Guidelines for Canadian Drinking Water Quality either for health reasons or aesthetic reasons.

A wide variety of microorganisms were chosen for analysis to try to get a more representative profile of the microbial population of the water sample (Emde, 1995). The microbiological enumerations that were performed by the Membrane Filtration technique were: Total Coliforms(TC), Fecal Coliforms(FC), Heterotrophic Plate Counts(HPC), Fecal Streptococci(FS), Klebsiella, Yeasts and Molds. Total Coliforms and Fecal Coliforms are regulated in the Canadian Drinking Water Quality Guidelines therefore, any drinking water study would be negligent if these two microbial indicators were not assayed. The Fecal Streptococci group of bacteria are comprised of species from the Streptococcus genera that possess the Lancefield group D antigen (WHO, 1993). Fecal streptococci are more numerous than coliforms in the feces of farm animals, cats, dogs and rodents. Therefore, coliform:streptococcus ratios have been used to try to determine the source of the coliforms found in waters. Ratios greater than four are thought to be found in domestic wastewaters, whereas ratios less than this are thought to be from animal or other sources. Klebsiella was chosen because these organisms have been associated with pulp mill wastes (Emde, 1995). Therefore, due to the relatively large number of pulp mills in the Northern River Basins Study area, the enumeration of these microorganisms may provide insight into the effects that some of these mills may have on the water systems. Yeasts and Molds are types of fungi that are found in the aquatic environment. Yeasts and Molds in a water supply are associated with taste and odour problems in drinking water and were therefore also included in the analysis (Emde, 1995). In addition, due to the thick cell wall of yeasts, these organisms have been found to be resistant to disinfection by free chlorine, and are frequently reported in finished drinking water supplies (AWWA, 1990). And finally, Heterotrophic Plate Counts were assayed to determine the general population numbers of both slow growing (7 day HPC)and fast growing bacteria (48hour HPC) that are likely related to pathogenic types that may be present in sewage pollution (McFeters, 1990). Ideally, it would have been good to sample for viruses and protozoans as well, but due to the associated time, complexity and high cost of these analyses, it was deemed to be beyond the scope of this study. For example, a single Giardia analysis requires a very large volume of water and can cost several hundred dollars. With these constraints in mind, viruses and protozoal agents were not analyzed for in the samples collected.

3.7.2 Discussion of Results

The results of all physical, chemical and microbiological analyses done on the samples are presented in Table C-1 to Table C-16 in Appendix C. The results are organized in tabular format in this

Appendix for each category of non-conventional drinking water collected. These results are discussed below.

Conventionally Treated Water

The assessment of the conventionally treated water can be used as a reference for assessing some of the non-conventional sources of drinking water. The microbiological MAC guidelines are met for the conventional drinking water samples obtained from the Atikameg Health Unit and the John D'Or Prairie Cistern. However, it should be noted that the free chlorine concentration found at the John D'Or Prairie cistern is below 1.0 mg/L. This could be a result of the time lag between collection and testing. This low chlorine concentration also explains the significantly higher levels of HPC bacteria and yeasts and molds at the John D'Or Prairie site than that seen in the treated water at Atikameg. The drinking water from the John D'Or cistern should be resampled to see if the free chlorine concentration is low again. The trihalomethane MAC guideline value is 100ug/L for treated drinking water. This has been exceeded in the John D'Or Prairie Cistern water. In addition, some aesthetic related guidelines have been exceeded in the conventionally treated water from both locations, notably iron and colour.

Surface Water

There are many physical, chemical and microbiological parameters in the surface waters tested that do not meet the guideline values recommended in the GCDWQ (1993). Based on this, drinking untreated surface water could pose a serious threat to health. All of the samples collected were positive for total coliforms which are used as an indicator of the pathogenicity of water. In addition, the general bacterial populations are fairly high. Old Fort is the site discussed earlier with the improperly constructed outhouse. Since the coliform:streptoccoccus ratio at this site is greater than four, this suggests that some of the scattered human waste may have run off into the nearby lake resulting in fecal contamination.

The turbidities of the surface water samples were highly variable ranging from 3NTU to more than 100NTU. Therefore, none of the surface water samples meet the MAC for turbidity (unless it can be shown that disinfection at Little Red River and Wentzel River would not be compromised by turbidities of 3 and 5 respectively).

The metals analysis of the surface water samples indicate that if the water from Lawrence Creek, Lawrence River, Birch Creek or Little Red River was consumed over a lifetime without treatment, that there is a potential health risk due to the consumption of mercury. Mercury is found in two forms in the aquatic environment. In the water phase, mercury is an inorganic salt that is poorly adsorbed in the gastrointestinal tract. However, sediments and fish contain organic methyl mercury that targets the central nervous system and can cause impaired mental and motor functions or even death (AWWA, 1990). It is possible that some of the mercury in the samples for all four of these locations was due to mixing up of the bottom sediments during collection. Specific events at each of the sites can be recalled in which the bottom sediments were stirred up. At Lawrence Creek and Birch Creek this was a result of having to break a hole in the ice to reach the water underneath, and at Little Red River and Lawrence River, the sediments were likely stirred by the sample collector standing on the sediment-embedded rocks to collect the sample. Therefore, before any conclusions can be drawn, these sites should be resampled. Manganese was also exceeded in several of the surface water samples but manganese is only regulated for aesthetic purposes.

Raw water quality in any surface water source is highly variable at best. There are so many factors that can influence the quality of the water. For example, surface water quality is influenced by the occasional recirculation of organisms trapped in bottom sediments. Studies have shown that there can be a 100-1000 fold increase in fecal coliform bacteria in the bottom sediments compared to the overlying waters. This recirculation may become particularly important when considering the water turnover events that occur in the spring and autumn of each season in which the thermal stratfication of the water bodies influences water movement (McFeters, 1990). Also, storm events can influence the microbiological quality of raw water supplies. The water quality deterioration that occurs after a storm event relates to all land uses over the drainage basin. Storm events typically brings elevations in suspended solids, organic demand materials and organisms to the drainage basin (McFeters, 1990). It is possible that both of these influences were factors during the field trip to the Peace-Athabasca Delta since it was in the autumn and it was raining.

The snow water samples collected near Atikameg contained coliform organisms. The sample that was collected closer to the townsite contained considerably more coliforms than the sample collected farther away in a remote area in the woods. The pH of the snow water is less than that of other surface sources collected in this study. The turbidity of the melted snow samples is 5.24 for the snow closest to the Atikameg townsite and 7.55 for the snow water collected near Twin Lakes. Neither of these turbidity measurements are in compliance with the guideline value of 1NTU set in the Guidelines for Canadian Drinking Water Quality(1993).

Ground Water

During the course of this study there were two groundwater samples analyzed. Fox Lake Well is a wide diameter well that serves as the domestic supply of water for a family living in Fox Lake. The water from this well is piped about 50m from the well to the home. Sacred Spring is the other groundwater sample. This sacred spring is located about 35km from the town of John D'Or and people travel here throughout the year to collect this special water for drinking purposes. Sacred Spring is a good example of the water table/aquifer meeting the surface of the earth and providing a bountiful supply of water. This is an unprotected spring in that the supply of water flowing from the bank is not encased in any man-made structures. From looking at the groundwater results in Appendix C, it does not appear as though this has had a great influence on the quality of the water obtained even though the water from Sacred Spring is prone to all of the problems associated with surface water supplies since it is not protected. It is interesting to note that the turbidity of the protected covered well is well above the GCDWQ limit of 1NTU. Perhaps this is due to entrapped carbon dioxide air bubbles in the water. This supply should be resampled for turbidity and the air bubbles removed prior to analyzing for turbidity to see if this makes a difference. Also, the aesthetic limits set for iron and manganese were exceeded in this well. One further note to make is regarding the very high conductivity that is evident in the ground water supplies, particularly at Sacred Spring.

This can be explained by the fact that groundwater contains more inorganic constituents compared to surface water, because ground water comes into contact with all types of minerals in the rock strata that surface water never touches (Gabler, 1988).

Bottled Water

There were two types of bottled water sampled. Both were purchased at a store in Atikameg on February 28, 1995. The Bottled Ozonated Water was stored in the refrigerator in a 2L plastic container. The Bottled Spring Water came from High Prairie, Alberta and was stored on the floor of the store in 16L plastic containers. These bottled waters meet the guidelines for both turbidity and coliform concentration. But, it should be noted that the HPC counts for both brands of bottled water are extremely high. As discussed earlier, some of the bacteria in HPC counts are opportunistic pathogens. This could have serious implications for people with decreased immunity including the very young, the very old, immunocompromised individuals and the sick.

Point-of-Use Devices

The effectiveness of one type of POU treatment device being used in Atikameg can be assessed by looking at samples of the influent water (in this case the Atikameg Health Unit Sample) and comparing the results with the effluent water labelled Atikameg POU Treatment Filter. The results are very interesting. This particular unit was effective at reducing the turbidity, the chlorine taste, the free chlorine residual, the total chlorine residual and the total organic carbon. Due to these capabilities, researchers are led to believe that the active ingredient in this unit is activated carbon. This is substantiated by looking at the microbial data. Although the concentration of coliforms in the influent was less than 1cfu/100mL, the concentration in the effluent from this unit had 9cfu/100mL. An increase in other microbial parameters were also seen including yeasts, molds, and the general bacterial population. Therefore, it appears as though these bacteria have colonized the treatment filter and are released into the effluent water in higher concentrations than were in the influent water. Therefore, without proper maintenance and frequent replacement of these filters, point-of-use devices such as these may constitute an additional risk to health.

Trihalomethane Formation Potential Analysis

Table C-16 tabulates the results of the Trihalomethane Formation Potential (THM-FP) analysis performed on raw water samples from the first two field trips. Essentially, THM-FP involves dosing a 250mL water sample with an excessive quantity of chlorine so that all of the trihalomethane precursors in the water sample will react with chlorine and the maximum concentration of trihalomethanes can be formed without being limited by free available chlorine. Unfortunately, the chlorine dose used in the experiments was insufficient and there was no free chlorine residual after the 7 day reaction period. Trihalomethane concentration was determined for each sample before and after dosing using liquid-liquid extraction with a Hewlett Packard 5790A Series gas chromatograph.

The Trihalomethane concentration found in the raw water samples was well below the GCDWQ limit of 100μg/L. This limit was exceeded in the Treated water sample at John D'Or Prairie. Also, it is interesting to note that chloroform is typically the largest component of the trihalomethane concentration followed by bromodichloromethane, dibromochloromethane and bromoform. However, larger amounts of brominated compounds, relative to chloroform indicate a higher concentration of dissolved bromide in the water (American Public Health Association et al., 1992). This is the case for Wentzel River. None of the raw water samples contained bromoform. The existance of chloroform in the raw water samples is very small and may be a result of contaminated reagents or glassware.

The THM concentrations are very high after both the 3:1 and the 6:1 Chlorine:TOC dosing. The 3:1 dosing was obtained from prior THM-FP analyses performed at the University of Alberta Environmental laboratory. After the first experiment was complete and it was found that there was not any chlorine residual left over, it was decided to re-run some of the same samples at the 6:1 dose. This dose was still inadequate to provide for an excess free chlorine residual, but trends in the data can be analyzed nonetheless. The potential formation of trihalomethanes certainly seems to be correlated with the Total Organic Carbon concentration. The higher the TOC, the more potential that sample has to form trihalomethanes if chlorine is added. Chloroform is in the highest concentration followed by successive brominations in the order of bromodichloromethane, dibromochloromethane, and bromoform. The concentrations of detectable trihalomethanes were higher after the 6:1 chlorine dose than after the 3:1 chlorine dose.

3.8 ASSESSMENT OF PORTABLE POINT-OF-USE WATER TREATMENT FILTERS

3.8.1 Portable Drinking Water Filters on the Market

Currently, there are a wide variety of portable water filtration units on the market. The filters are typically hand held units that are pumped to force the water through the media, although gravity fed units and suction straw-type devices are also available. The filter media is either permanently encased in the units or else it comes in replaceable cartridges. There are many types of media utilized in these units including activated carbon, polyethylene, iodinated resins, silver impregnated ceramic, pleated paper,and proprietary material. Proprietary material means that the manufacturers will not disclose the ingredients of the active agents to protect the formula from being used by other manufacturers. Researchers of the Drinking Water Component did a survey of camping and wilderness stores in the Edmonton area to find out what types of portable filters were available. The types of units found during this survey, along with some of the manufacturers claims about these units, are presented in Table 8. The information in this table was gathered from: (1) visits to Edmonton retail stores; (2) information found in the manufacturers instructions included with each unit; (3) an article by Getchell (1994) in the March 1994 issue of *Backpacker* magazine; and (4) information in the 1994 issue of the *Outdoor Retailer* magazine.

Table 8. Types of Portable Drinking Water Treatment Filters Available At Edmonton Retail Stores.

Filter Media	Type of Filter	Absolute PoreSize (μ)	Output (L/min)	Weight (g)	Capacity per cartridge (L)	Cartridge Price ($)	Unit Price ($)	Rank by Initial Cost	$/1000L	Rank by $/1000L	$/10000L	Rank by $/10000L
1. Carbon	Pump	0.4	0.88	425	378	50	90	10	190	11	1390	13
2. Carbon	Pump	0.5	0.57	198	45	16	50	3	402	17	3602	16
3. Carbon	Pump	0.3	1.14	312	757	40	80	8	120	5	600	7
4. Carbon and Surface Filter	Pump	0.02	1.19	510	94	21	130	12	340	15	2356	15
5. Carbon and Surface Filter	Pump	0.5	1.14	312	800	38	58	5	96	2	514	6
6. Carbon and Ceramic	Gravity	0.9	0.28	680	3785	60	100	11	100	3	220	1
7. Silver Impregnated Ceramic	Pump	0.2	0.4	227	3785	85	170	14	170	8	340	3
8. Silver Impregnated Ceramic	Pump	0.2	0.74	652	15141	134	300	16	300	14	300	2
9. Ceramic and Surface Filter	Pump	0.02	0.85	510	378+	28	150	13	206	12	878	9
10. Iodinated Resin	Pump	N/A	0.28	57	50	Not Replaceable	35	1	700	19	7000	19
11. Iodinated Resin	Pump	N/A	0.4	170	200	45	70	6	250	13	2275	14
12. Iodinated Resin	Pump	1	1.7	567	2000	60	180	15	180	10	420	4
13. Iodinated Resin	Pump	1	1.14	340	750	54	85	9	139	6	787	8
14. Iodinated Resin	Pump	1	0.57	340	400	45	85	9	175	9	1165	12
15. Iodinated Resin	Gravity	N/A	0.28	170	378	Not Replaceable	37	2	111	4	999	11
16. Iodinated Resin	Gravity	N/A	0.57	567	94 to 378	40	57	4	457	18	4297	18
17. Iodinated Resin	Straw	N/A	Unknown	Unknown	95	Not Replaceable	35	1	385	16	3710	17
18. Polyethlyene	Pump or Straw	2[a]	0.75	Unknown	378	17	35	1	69	1	477	5
19. Unknown	Gravity	Unknown	Unknown	450	900	Not Replaceable	75	7	150	7	900	10

Notes: [a]This is a nominal pore size rating. An absolute rating was not available.
N/A = Not Applicable or Not Available.
Unknown = Information not found by the authors of this report.

Since most of the units are made in the U.S.A., the values were converted from imperial to metric. The prices are approximate Canadian dollars at the time of the survey and were obtained by taking the average price of the unit in all Edmonton stores surveyed. Each unit was then ranked according to cost. First, all of the units were ranked based on the inital cost to the buyer, from the cheapest to the most expensive. Then, the units were ranked based on the cost per 1000L and also based on the cost per 10000L. From this ranking, it is apparant that more than just the initial cost should be considered when purchasing a treatment device. For example, by looking at Filter #10, it is one of the cheapest units to buy based on the inital price, but the most expensive to buy if large volumes of water will be filtered. This is due to the extremely low capacity of the unit. The design of the unit is also important to consider when choosing a device to buy. The gravity type filters are typically larger and more cumbersome and filtering takes longer. Probably the most important factor when purchasing a portable point-of-use water treatment filter is whether or not these units actually work. The pore size ratings should give some indication of the effectiveness of removal of microorganisms and other particles in the water. The pore size is the size of the openings in the filter element. An absolute rating means that the filter will not pass any particles below the given size, whereas a nominal pore size rating indicates that "most" particles below the given size are removed (Getchell, 1994). According to Getchell (1994) a pore size rating of 0.2μ is required to filter out bacteria, a pore size of 4μ is required to filter out protozoa such as *Giardia*, and a pore size of 0.0004μ is necessary to filter out viruses. Due to the small pore size required to filter out viruses, there are not any filters that can effectively remove viruses by occlusion alone. However, some of the units have iodine in them, which may act as a disinfectant to kill viruses.

After researching the various types of filters on the market, the authors of this report decided to further investigate the effectiveness of some of these filters to determine if they would be suitable for people in the Northern River Basins Study area that live off of the land. This investigation was felt necessary because little scientific information is available to assess their performance. Given that the results from the sampling program indicated that some form of treatment is required in most cases, particularly if the water is obtained from a surface source, a testing program was undertaken to determine if these filters were viable options for living off the land expediditons. This assessment was done by vigorous laboratory testing of selected units under worst case conditions and is described below.

3.8.2 <u>Protocol for Assessing Portable Filters</u>

The first step in the lab testing was to select suitable filters for testing. There were several factors involved in the decision making process. In Table 8 it can be seen that there are four general types of filter media used in these portable treatment devices: (1) activated carbon, (2) ceramic, (3) iodinated resins, and (4) polyethylene. Initially, it was thought that one unit would be chosen for analysis from each type of filter media. However, after further research, it was decided that for this project, the assessment of the units containing iodine was unnecessary. There were three main reasons governing this decision. First and foremost, it appears that many of the residents of Northern Alberta have not acquired a liking for the taste of chlorine in their drinking water. If they have not acquired a taste for chlorine, then it is not likely that they will find the flavour of iodine pleasing.

Second, as outlined in Protocols for Point-of-Use Devices Guide Standard and Protocol for Testing Microbiological Water Purifiers (USEPA, 1987), non-purifying units that rely primarily on occlusion can be tested using 4-6μ particles instead of live *Giardia* organisms. Third, worst case conditions for units containing iodine are different than for units that do not contain iodine. That is, the worst case challenge for iodinated units involves using a test water with a low pH whereas non-iodinated units are challenged by high pH waters.

Three different types of filters were chosen for further laboratory analysis. These filters were chosen to represent the larger industry as a whole. One of the most expensive ones on the market, the cheapest one available and a mid-price-range filter were chosen. Each is from a different manufacturer. Each unit has a different type of media with which it filters the water. From Table 4 the filters chosen for testing were the filters labelled 5, 7 and 18. Filter 5 has an activated carbon core pre-filtered by a pleated paper filter, Filter 7 utilizes a silver impregnated ceramic, and Filter 18 is a polyethylene matrix filter. For the purpose of this report, these units will be called "Carbon", "Ceramic" and "Plastic" respectively.

It was decided to test these three filters under worst case conditions that could possibly occur in the Northern River Basins Study. To do this, a suitable challenge water had to be developed. Due to the large volume of water that was to be filtered, it was not feasible to use actual water samples from the NRBS area. Therefore, a challenge test water was created under carefully controlled laboratory conditions to try to represent a worst case scenario that would be expected in the Northern River Basins. To determine the levels of the parameters in the test water, raw surface water data from the NRBS area was analyzed. This data came from samples taken in the Treated Water Survey and from samples taken on field trips during the course of this study. Based on this raw water data and on literature on other challenge waters made, the test water was created to have the characteristics listed in Table 9.

Table 9. Challenge Test Water Characteristics

Parameter	Challenge Level	Ingredient
Water		Distilled Water
E. coli challenge	10^6cfu/100mL	Pure culture E. coli (ATCC 13706) suspension
Total Organic Carbon	20mg/L	Humic Acid and Glucose
Total Dissolved Solids	180mg/L	Sodium Chloride (NaCl)
pH	8.0	NaOH or HCl
Turbidity	30NTU	S.A.E Fine Test Dust
Particle Sizes	Ranging from 1μ to >50μ	S.A.E Fine Test Dust

The USEPA's document entitled Protocols for Point-of-Use Devices Guide Standard and Protocol for Testing Microbiological Water Purifiers was consulted for ingredients to use to simulate this challenge water (USEPA, 1987). The appropriate amounts of each ingredient to be added was determined through preliminary laboratory testing. The test water was prepared in a 120L container each day of the actual experiment. After all of the ingredients were added, the test water was left to mix at 600rpm for approximately one hour so that the bacteria had time to acclimatize to the new conditions. The mixing continued for the duration of the filtering to keep all of the ingredients in suspension.

The basic experimental design used to evaluate these filters was a simple one way Analysis of Variance (ANOVA) in which triplicates of each unit were subjected to the same treatment. This design allows for comparing "between" and "within" treatments (Box et al., 1978). In other words, the difference *between* the different types of filters (i.e. Carbon vs Ceramic vs Plastic) can be analyzed, as well as the difference *within* each triplicate of filter type (i.e. Carbon Filter 1 vs Carbon Filter 2 vs Carbon Filter 3).

Three prototype water filters of each brand were set up and conditioned according to manufacturers instructions prior to starting the tests. This involved filtering 1L of water through the Carbon unit, filtering water through the Ceramic unit until it was "optically clear", and nothing for the Plastic filter. To keep the filtered volumes uniform, 1L of distilled water was filtered through each unit prior to the onset of the challenge testing. It should be noted that this 1L-conditioning is not included in the Total Volume Filtered in the results discussed later in this report.

The three triplicate filters were mounted upright with metal strappings onto a piece of wood. The handles of each filter unit were attached to another piece of wood using hose clamps and screws. This was done so that each unit could be pumped uniformly. The boards were attached to the side of a laboratory bench using C-clamps during the pumping cycles. The units were pumped manually (just as they would be in the field) at the rate specified by the manufacturers. At the onset of each experimental day, a pre-determined volume was set to be filtered. Influent and effluent samples were taken at 1L, 4L, 6L, 8L, 10L and 20L. The influent and effluent samples were analyzed for turbidity, particle counts, and *E.coli* concentration. Turbidity was measured using a portable digital Hach turbidimeter that was calibrated using prepared formazin standards. The particles were counted using a Hiac/Royco Particle Analyzer and the channels were set to count particles in the following ranges: (1) 1 to 2 microns; (2) 2 to 3 microns; (3) 3 to 4 microns; (4) 4 to 5 microns; (5) 5 to 10 microns; (6) 10 to 25 microns; (7) 25 to 50 microns; (8) greater than 50 microns. Particle counts per mL were established for each range based on 10mL samples analyzed by the Hiac/Royco instrument. Samples were diluted with distilled water to be within the countable range of the instrument if necessary. The microbial analysis was done using the membrane filtration technique described in Standard Methods for the Examination of Water and Wastewater (American Public Health Association et al., 1992). The *E.coli* organisms were enumerated on mEndo media after a 24 hour incubation at 35°C. The samples for the microbial assays were collected in sterile flasks. The samples collected from the silver impregnated ceramic units were neutralized with 10mL of Chamber's solution (7.3% sodium thiosulphate and 5% sodium thioglycolate) per Litre of sample immediately after collection (USEPA, 1987; Environmental Health Directorate, 1980). Triplicate analyses were performed on all membrane filtrations and all particle counts.

3.8.3 Results of Portable Filter Assessment

The results of the portable drinking water treatment filter assessment are located in Appendix D. The averages obtained for each unit for the turbidity, microbial and particle analyses are presented in a series of tables and graphs in this appendix. These results are discussed below.

Turbidity Analysis

The target influent turbidity was 30NTU. Only the ceramic unit was able to reduce this influent turbidity to below the Canadian Drinking Water Quality Guideline value of 1 NTU. Figure D-2 illustrates that the ceramic unit is the most efficient at reducing the turbidity. It also appears that there was a very slight initial conditioning period in which the turbidity reduction gets better. Table D-1 has turbidity levels for the Ceramic unit for Litre-17 and Litre-18. The reason that turbidity was measured at these volumes was because the pumping of the filters had become noticeably more difficult indicating that the pores had become blocked and the unit needed to be cleaned as explained by the manufacturer. This "regeneration" involved removing the filter element from the filter housing and scraping the ceramic filter under running water with the "regeneration brush" supplied until the bright natural colour of the ceramic reappeared. It is interesting to note that the turbidity following this regeneration is significantly higher than just prior to the scraping. This is typical of other filters after they have been backwashed.

The turbidity reduction for both the Carbon and the Plastic unit were less than for the Ceramic unit. Unlike the Ceramic filter, the percent turbidity reduction decreased for these other two units for the first 6L and then seemed to level off somewhat from 10L to 20L. The Carbon and Plastic curves illustrated in Figure D-2 illustrate a minimum inflection point at 6L. This low percent turbidity reduction is correlated with higher turbidity levels at 6L of water filtered. There are two possible explanations for this increase in turbidity at this volume filtered. First, in the other samples collected there was at least 1L of water filtered through the units prior to collecting the samples for analysis. On this particular day, the first liter filtered(which was Litre-6) was the volume collected for the analysis. Therefore, any residual turbidity causing particulates would not be discarded as they would be in the other samples collected. Second, prior to collecting the 6L sample, there was a 2 day stagnation period in which the filters were not used. It is possible that during this time, bacteria colonized the filter and were then sloughed off in the first litre of water collected after the stagnation period. These extra microorganisms may have contributed to the higher turbidities.

Microbial Analysis

As described earlier, often microbial removal is described in terms of "logs" which is illustrated in Table 10.

Table 10. Correlation of Log Reductions and Percent Removals.

Percent Removal Convention	Log Reduction Convention	Log Reduction Example: Effluent concentration after 10^6cfu/100mL Influent challenge:
90%	1-Log reduction	10^5cfu/100mL
99%	2-Log reduction	10^4 cfu/100mL
99.9%	3-Log reduction	10^3 cfu/100mL
99.99%	4-Log reduction	10^2 cfu/100mL
99.999%	5-Log reduction	10^1 cfu/100mL
99.9999%	6-Log reduction	<1 cfu/100mL

The silver impregnated ceramic unit was very effective at removing the *E. coli* in the influent challenge water. Over the whole experimental test period, the effluent *E. coli* concentration was consistently <1cfu/100mL, which corresponds to a 6-log reduction. Regunathan and Beauman (1987) state that "*Escherichia coli* is readily killed by low levels of silver" and "there have been numerous unpublished reports of the bactericidal effect of silver on the common enteric pathogens, but these reports have not been confirmed." Even though the silver currently in silver impregnated filter materials may inactivate *E.coli*, other heterotrophic bacteria are more resistant (Geldreich et al., 1985). Measuring the HPC in the influent and effluent of these filters is a sensible recommendation for further study.

The microbial removal in the other two units was less than ideal. Even the first litre of water filtered contained very high concentrations of *E.coli*. In the Plastic unit, the growth on the mEndo plate was so great that the colonies were *Too Numerous Too Count* (TNTC). For subsequent assays, appropriate dilutions were made. Figure D-4 illustrates that the Carbon unit has a slightly better percent removal than the Plastic unit over the course of the experiments, but by the eighth litre of water filtered, both the Carbon filter and the Plastic filter had less than a 1-log bacterial reduction. Figure D-3 effectively illustrates the increasing microbial concentrations in the Carbon filter.

Activated carbon filter media provides an ideal environment for bacterial growth because it chemically reduces chlorine, and bacteria can grow on the surface of the activated carbon (Drinking Water Health Effects Task Force, 1989). Culotta (1989) also talks about this bacterial contamination of activated carbon media, and explains that this is why activated carbon filters "should only be used to treat water that is microbiologically safe." Although it is not evident from the graphs and tables in Appendix D, it is interesting to note that one of the Plastic filters actually contributed *E.coli* to the effluent water at 6L of water filtered. This certainly points to bacterial colonization and proliferation in this particular unit during the 2 day stagnation period prior to the 6L collection.

Particle Analysis

As described above, the particle counts were divided into eight ranges: (1) 1μ to 2μ; (2) 2μ to 3μ; (3) 3μ to 4μ; (4) 4μ to 5μ; (5) 5μ to 10μ; (6) 10μ to 25μ; (7) 25μ to 50μ; and (8) greater than 50μ.

The particle counts and graphs are presented in Table D-5 to Table D-18 and Figure D-5 to Figure D-18 in Appendix D.

The smallest size particle that can be counted by the Hiac/Royco particle analyzer is 1μ. Therefore, the 0.2μ and 0.5μ claims made by the manufacturers of these devices can not be precisely tested. However, by looking at the particle counts in the 1μ to 2μ range, it is evident that some particles in this range still manage to squeeze through the filter media, so the absolute ratings supplied by the manufacturer are not necessarily accurate. Once again, the Ceramic filter is the most efficient and has the highest percent reduction. The percent particle reduction increased over time as the filter pores becamed clogged until after the cleaning event after Litre-17. After the filter scraping of this ceramic unit, the particle counts in all of the ranges measured increased. This corresponds to the increased turbidity also noticed at Litre-18. The average particle counts for the Carbon and the Plastic unit are typically greater than for the ceramic unit. This would be expected from the higher pore size ratings given by the manufacturers of these units.

Particle counts can be used to evaluate how effective filters may be at removing *Giardia* cysts. *Giardia* can exist as a trophozoite 9μ by 21μ, or as an ovoid cyst, 6μ by 10μ (AWWA, 1990). Therefore, it is interesting to look at the smaller of these two sizes and look at the particle counts in the 5μ to 10μ range. The results of the particle counts in this range are presented in Figure D-13 and Figure D-14 in Appendix D. For the Ceramic unit, there is consistently a 3 log reduction and sometimes a 4 log reduction of particles in this range (with the exception of the first litre of water filtered). Both the Plastic filter and the Carbon filter only get a 2 log reduction at this range of particle sizes. Initially, the Plastic filter was slightly more effective at this size range, but from 6L to 20L, the Carbon filter had a higher percent removal. A similar trend can be seen over the other particle size ranges as well.

The results of the Portable Drinking Water Treatment Filter Laboratory Testing just discussed were acheived under specific test conditions and are not necessarily definitive for all units under a variety of other conditions that may be experienced under actual operating conditions. Nonetheless, significant differences between different types of units were seen and certainly, the effectiveness of the Carbon and Plastic unit is questionable, because neither of these units had more than a 1-Log *E. coli* reduction after the sixth litre of water filtered. These poor microbial removal results for the Plastic and Carbon filters should be made known to potential users.

4. DISCUSSION

The Assessment of Non-Conventional Drinking Water in the Northern River Basins Study involved compiling and synthesizing data based on the findings from four different types of scientific study including: (1) the review and synthesis of existing information; (2) social scientific research; (3) sample collection; and (4) laboratory analysis. Once all of the information was gathered from each of these areas of research, the results were compiled and conclusions drawn. The main findings and the limitations associated with each of the types of research in the present study are discussed below. Recommendations for further study are also proposed.

4.1 REVIEW AND SYNTHESIS OF EXISTING INFORMATION

The initial work that the authors of this report were involved in was to review existing literature pertaining to the assessment of non-conventional drinking water in the NRBS area. The existing data and information was compiled and presented in the findings and results section of this report. The correlation between drinking water quality and health was highlighted by discussing the many waterborne diseases that can be transmitted through drinking water. The transmission of water related illnesses is multi-factorial and depends on the communities sanitation practices, cultural and socioeconomic characteristics of the population, degree of treatment utilized, endemic levels of disease and other environmental factors (McFeters, 1990).

Based on past studies, an attempt was made to try to assess the general health of people living in the NRBS area. Waterborne disease statistics derived from a study by Emde et al., (1994) were examined to try to determine the level of waterborne illness up north. It should be noted that the health unit records and disease summaries were not detailed enough to determine whether or not water was the vehicle of transmission. (Emde et al., 1994). Also, the reported incidence of waterborne disease does not necessarily reflect the actual incidence. This could be a result of :

1. The illness may not be associated with consuming contaminated water.
2. The individual may not seek medical attention.
3. Other health conditions may overshadow waterborne illnesses.
4. Medical facilities may not adequately investigate the situation in order to determine an etiological agent
5. Laboratory analysis may fail to detect the actual causative agent. The number of known microorganisms capable of causing waterborne diseases continues to grow, and new concerns about disease transmission, including viruses and parasites are still being identified.

Therefore, as a result, only a fraction of waterborne disease outbreaks may be recognized, investigated and reported (Moore et al., 1994; Rose, 1993; Sobsey et al., 1993; Drinking Water Health Effects Task Force, 1989). Nonetheless, there is a strong relationship between waterborne disease outbreaks and drinking contaminated untreated or inadequately treated water (McFeters, 1990). Therefore, there is a strong relationship between drinking contaminated water and human health.

Existing information regarding non-conventional sources of drinking water and non-conventional drinking water treatment practices in the area was also pursued. Although there was some information about the number of dugouts and wells in the area, data on the extent, utilization , and water quality of other non-conventional sources of drinking water in the NRBS area was limited to non-existent. Drinking water officials across the country were contacted to see if they knew of any studies pertaining to this topic, but all answered that there were not any that they knew of (Jackson, 1995, Ramsom, 1995, Robertson, 1995, McIntosh, 1995, Ghostkeeper, 1994, Bingham, 1994) There were, however, three studies in progress at the time of completion of this report that are also involved indirectly in the assessment of non-conventional drinking water in the NRBS area. The first of these studies is the work being carried out by the Traditional Knowledge Component of the Northern River Basins Study. The survey instrument being used by this group includes valuable questions pertaining to the assessment of non-conventional drinking water in the NRBS area. The survey asks questions about water use, water sources, water quality and non-conventional methods of treating the water (Traditional Knowledge, 1994). In addition, there are also questions regarding water quality, changes in the waters, and perceived health effects of drinking water quality (Traditional Knowledge, 1994). Obviously, the results of this study are invaluable to the assessment of non-conventional drinking water in the Northern River Basins. A summary of some of the results obtained from this survey have been included in relevant sections of this report. However, the compilation of many of the other results, particularly, the breakdown of responses for each community interviewed are still in progress and are currently unavailable (Bill, 1995). The second study in progress is a telephone survey being administered by the Other Uses Group of the NRBS. This survey is aimed at obtaining an understanding of the varied uses of the water bodies by residents in the Northern River Basins Study area. This survey likely includes some questions that would be particularly relevant in the assessment of non-conventional drinking water in the NRBS area. This results of this telephone survey are expected sometime soon. The third study of relevance to the assessment of non-conventional drinking water is the Drinking Water Survey which is a two year (1992-1994) sampling study administrated by Alberta Environment (Flett, 1994a; Jackson, 1995). This study involved routine sampling at six remote locations in the Peace-Athabasca Delta where people in the area use the water for consumptive purposes. Presently, the results from this study have not been compiled and are currently unavailable (Jackson, 1995).

4.2 SOCIAL SCIENTIFIC RESEARCH

Social scientific research involves studying people and aims to determine logical and persistent patterns of regularity in social life (Babbie, 1992). Since people are dynamic and changing, social research is an "open-ended enterprise in which conclusions are constantly being modified (Babbie, 1992)." The practice of social scientific research itself has many limitations and as Babbie (1992) points out, there are many errors involved in personal human inquiry such as:

1. Inaccurate observation
2. Overgeneralization
3. Selective Observation
4. Made-up information to explain away confusion and contradictions
5. Illogical Reasoning
6. Ego involvement on behalf of the researcher
7. Premature closure of inquiry
8. Mystification (attributing supernatural causes to phenomenon that are not understood)
9. Human error because to err is human.

These sources of error should be considered when interpreting a social scientific research report of any sort. This one is no exception.

A large part of this assessment of non-conventional drinking water involved questioning residents of the Northern River Basins regarding their drinking water practices. For the most part, these interviews were unstructured which is usually more appropriate for field research of this type (Babbie, 1992). Those interviewed were asked about their sources of drinking water, what the water was used for, and what sort of treatment, if any, was applied before consumption. In addition, questions regarding the water quality of the source utilized and perceived health effects of drinking water were also asked. Prospective interviewees were attained by "snowball sampling". This is a method in which the interviewer asks one participant in the study to recommend others for interviewing and so on and so on (Babbie, 1992). The results of these interviews are presented throughout the results section of this report. It should be noted that the individual responses of people interviewed do not necessarily reflect the attititudes and practices of all residents in the Northern River Basins Study. That is, surveys such as this one "cannot measure social action; they can only collect self-reports of recalled past actions of prospective or hypothetical actions (Babbie, 1992)."

The assessment of non-conventional drinking water in the Northern River Basins certainly has a traditional and perhaps a cultural component to it. Therefore, in approaching this study, researchers were not trying to find a reason to undermine traditional ways, rather, the focus was to try to gain an understanding about them. Unfortunately, as a university researcher, and an outsider, there were many barriers involved in communicating this intent. First, in some of the areas visited, a language other than English was spoken. There will always be some meaning lost in translations. Second, people seemed suspicious of the motives behind collecting samples. For instance, Andrew Sewepagaham, from John D'Or Prairie, told someone that he hoped that I would not tell him that he could not drink his "special water" anymore. Rosie Chalifoux also said that she could not tell me who was using non-conventional sources of drinking water in the Atikameg area because people were afraid that I would tell them that they could not drink their "special water" anymore. This is not just the case with this research project though. Hugh Brody(1988), the author of Maps and Dreams, states that "it is never easy to know why research is being done, or whose intersts in the end will be served." This seemed to be a general consensus among people interviewed in the Fort Chipewyan area. Many people talked about how there were so many scientists doing studies in the area that claim to be to help them, yet they say that they have very rarely seen the results of such studies. The author of this report intends to send a copy of it to community representatives where the interviews were done, so that the people that were involved in the collection of information have the opportunity to see the results obtained. This may help to break down barriers for future studies. Another limitation to this data collection regarding non-conventional drinking water practices was the relatively short amount of time spent in the communities. To obtain a full understanding of some of the traditional ways of obtaining water, more time should be spent in the communities to get to know the residents, to gain their trust, and to actually participate in the activities that are being studied. For example, this may include taking part in a living-off-the-land expidition such as trapping. In this way, the actual method of collecting snow or ice for drinking water can be observed and maybe other aspects will be revealed that would not be observed otherwise. Another alternative may be to have the CHR's become more active researchers in a study of this nature in the future.

Some of the traditional views on what water means to the people was learned as a result of the social science research component of this study. Lea Bill (1994), one of the Traditional Knowledge Component leaders, had some words of wisdom for the researchers regarding the native perspective on water as described in the following excerpt:

> In the native view of life, everything has a spirit and all spirits must be treated with respect. The Water Spirit has not always been treated with the respect it deserves and therefore the spirituality of the water has changed. This is because people have put things into the water that have changed the Water Spirit. Also, the water flows in a certain way in a cleansing process. When water becomes diverted it will not necessarily cleanse itself the same way. The Grandfathers had some messages for the author of this report. These messages were passed on through Lea Bill. First, the grandfathers suggested that researchers "Look deeper." To do this, the ions, ionization energies, and the electricity of the water should be investigated. The Grandfathers also said to "look at the ions and how they interact with the water molecule." And the final message was to "consider the nutrients of the waters."

Interpretation and assessment of these concepts using normal scientific techniques is uncertain and difficult at best. Understanding all of the relationships between drinking water quality, health and personal beliefs is far from being known in a scientific sense. However, it has long been known that the perception is important in a person's assessment of drinking water quality.

Another aspect that should be discussed under this heading of social science is appropriate technology. The utilization of an appropriate technology implies that the system will be utilized, maintained and operated by those it serves (Okun, 1988). Appropriate technology begins with the involvement of the people affected in the decisions made. Drinking water treatment for remote areas in the NRBS must also be appropriate, taking into account local conditions, culture, economy and sociology.

4.3 SAMPLE COLLECTION

There were 20 samples of non-conventional sources of drinking water collected during the course of this study. This included samples of: (1) raw surface water from lakes, rivers and creeks, (2) groundwater from an unprotected spring and a protected well, (3) snow water, (4) bottled water, (5) point-of-use treated water , and (6) conventionally treated water (for comparative purposes). Unfortunately, samples of other sources of non-conventional drinking water were not obtained such as water from a dugout, rain water, or birch tree water. Perhaps these samples can be collected on the proposed field trip to Cadotte Lake in the spring of 1995. Nonetheless, the samples that have been collected and analyzed to date represent the start of a database on the physical, chemical and microbiological quality of some non-conventional sources of drinking water.

It should be noted, that the sampling itself provided an insight into the methods of non-conventional drinking water collection Sometimes, long distances were travelled to areas where people would collect "special" drinking water. Other times, this involved trekking through the wilderness to an appropriate place away from human activity. However, there are some limitations that should be discussed with reference to the sampling portion of this study. Many of the samples that were collected were raw water sources that local residents said were used for drinking water purposes. In some cases (particularly with the raw surface sources) these were not samples of actual water being consumed by individuals at the time of collection. Furthermore, for each site sampled, 4L of water were collected for analysis; 2L for microbial, and 2L for physical and chemical analysis. When the supply of drinking water is limited, such as at the remote camp on Prairie River where the residents hauled water in 5 gallon containers, 4 L is a large amount of water.

4.4 LABORATORY ANALYSIS

Scientific research based on laboratory derived results is not without its limitations. This can be highlighted by discussing the inherent problems associated with the microbiological analysis of water supplies. Results of routine microbial sampling should be interpreted with the awareness that each result is liable to two sorts of error, even if proper protocol is followed. First, there is sampling error because there is a variation in microbial density in different parts of the water being sampled. Second, there are many statistical inaccuracies that may be introduced by laboratory methods (Tillett, 1993).

The membrane filtration method that was used to assay the microorganisms in the lab analysis has its limitations in that the pores may become plugged if the water volume poured through is too great for the given microbial concentration, and the deposition of other material on the filter may interfere with bacterial growth . Also, the method of enumerating microorganisms is by counting colonies that have formed on a microbial growth media and assuming that one micoorganism produces one colony on this plate. There are problems with this assumption because particle associated microbes may not be registered as a colony forming unit. Current detection methods grossly underestimates the presence of these bound organisms Also, clumped microorganisms could be registered as a single colony forming unit when indeed large numbers of microorganisms are responsible for the colony. In addition, stressed or injured microorganisms may not be enumerated by the membrane filtration technique, yet these same organisms may still be able to produce infection and disease if consumed in drinking water (Sobsey et al., 1993). Other experimental error involved in laboratory analysis of water samples in due to human experimental error. Nonetheless, the results of the laboratory analysis of the samples taken illustrate general trends in the quality of the water.

A laboratory analysis of another nature was done during the assessment of the portable drinking water treatment filters. In this case, carefully controlled laboratory conditions were set up to try to simulate a worst case scenario that these filters could encounter. The limitation in a study of this sort is that the carefully controlled lab conditions do not necessarily reflect what would be experienced in the field. In spite of this, the results can still be interpreted and conclusions drawn based on the data obtained.

4.5 COMPILING RESULTS AND ESTABLISHING CONCLUSIONS

All of the information gathered over the course of this study from the four components described above was compiled, and the results, recommendations and conclusions obtained by the researchers are presented throughout this report.

5. CONCLUSIONS

Review of the literature found that little information is available on the use and quality of unconventionally treated water, both within the NRBS area and outside of it. Compared to conventionally treated water, almost no information is available, which is somewhat surprising since it has been estimated that 25% of the population in the Northern River Basins obtain their water from sources other than conventional treatment facilities. It would be expected that similar numbers would be found in other relatively remote areas in Canada.

The source of drinking water for the estimated 25% of people that do not obtain their drinking water from conventional drinking water treatment facilities are numerous. These people utilize non-conventional sources of water including: surface water, rain water, snow water, ice water, dugout water, well water, spring water, muskeg water, birch tree water and bottled water. These sources are typically used by people that live in remote rural areas or by people that live off of the land.

One of the results obtained from the survey by the NRBS Traditional Knowledge Component was that only 5% of the people interviewed received their water for daily use from a water treatment facility. It must be considered that the average age of the 221 people interviewed in this study was 58 years old and one of the qualifying criterion was that they must have lived off of the land at some point in their lives. It is possible that many of the people interviewed in this study may still be living off the land, hence the low conventional drinking water usage.

It is not known to what extent these non-conventional sources of drinking water are treated; if at all. Some of the non-conventional drinking water treatment techniques that may be used by people living in remote areas include: (1) "point-of-use" disinfection methods; (2) "point-of-use" mechanical separation methods; and (3) "point-of-use" multi-barrier treatment processes:

1. Point-of-use disinfection methods include boiling the water, chlorinating the water with chlorine tablets or chlorine bleach, and treating the water with iodine tablets. More sophisticated point-of-use disinfection units may employ ultraviolet light or ozone as the disinfecting agent.
2. Point-of-use mechanical separation methods that may be utilized by people that do not receive their drinking water from conventional treatment facilities ranges from filtering the water with cloth and sand to more sophisticated reverse osmosis membrane filters, ion exchange units and activated carbon units. There are also portable drinking water treatment filters on the market that are designed to filter small quantities of water at the point-of-use. These filters contain a variety of media types ranging from polyethylene, activated carbon, ceramic, and iodinated resins.
3. Point-of-use multi-barrier treatment processes will typically employ several unit processes in the treatment sequence, utilizing both disinfection and mechanical separation techniques to obtain a high quality of drinking water. In some cases, small scale conventional drinking water treatment plants, called "package plants", may be installed in individual homes in remote areas.

Non-conventional sources of drinking water may also be used by people that receive drinking water from a conventional drinking water facility. These non-conventional sources have been labelled "special drinking water" by the people that collect it and are used for cooking and drinking purposes and for making tea. It is hypothesized that older members of the communities may engage in this practice more frequently than the younger generation. A more in-depth look into a particular communities drinking water practices is necessary to establish the extent of "special drinking water" usage by people that do have access to conventionally treated water.

Many people in the Northern River Basins Study area do not like the taste of chlorine in their drinking water. Some people have turned to additional treatment of the chlorinated water to try to get rid of this chlorine taste. Some of the methods used include boiling, aerating the water and treating it with a point of use filter. Although some of these point-of-use devices are very effective at removing the chlorine taste and odour in the drinking water, these devices have their limitations, particularly those that contain activated carbon. It is a well established fact that activated carbon units harbour bacterial growth and can lead to an increased number of microorganisms in the water that it treats if they are not properly maintained and if the filters are not replaced regularly. Public education about the reason that water is chlorinated may decrease the opposition to chlorination in some communities in the NRBS area.

From the portable drinking water treatment filter assessment it was found that two of the three units tested (plastic media and activated carbon media) were ineffective at removing bacteria after the first litre of water was filtered. Therefore, these units are not recommended as the sole treatment of contaminated drinking water for the wilderness excursions they are intended for. It has also been concluded from this analysis that these units do not always live up to the claims made by the manufacturers. Further laboratory testing of the silver impregnated ceramic unit is necessary before it can be condoned as a viable treatment option for those that live in remote areas in the Northern River Basins or for those that live off of the land.

There are many physical, chemical and microbiological parameters in the surface waters tested that do not meet the guideline values recommended in the Guidelines for Canadian Drinking Water Quality. All of the samples collected were positive for total coliforms which are used as an indicator of the pathogenicity of water. In addition, the general bacterial populations are fairly high. Based on this, drinking untreated surface water could potentially pose a serious threat to health.

Initially, the assessment of non-conventional drinking water in the Northern River Basins Study was set out as a scientific-based study. However, it was quickly realized that there was also traditional and perhaps cultural aspects to the assessment of non-conventional drinking water; hence a large social scientific component. Therefore, although water samples can be analyzed by traditional scientific techniques, it is difficult to assess the overall impact that consuming non-conventional water will have when one must also consider the psychological edge that drinking "special water" may have for people. The problem is that it is difficult to encorporate belief systems into the scientific assessment of drinking water quality. Therefore, in approaching this study, researchers were not trying to find a reason to undermine traditional ways, rather, the focus was to try to gain an understanding about them.

There were many limitations in regards to the assessment of non-conventional drinking water in the NRBS as a result of the sociological component of this study. First, as is the case with any social scientific study, there are many potential errors in human inquiry and assessment. Second, in some areas in the Northern River Basins, there was a language barrier between residents and researchers. Unfortunately, researchers could not speak the language spoken by some of the people in the NRBS area, particularly the elders in the native communities. Third, many of the people interviewed seemed somewhat suspicious of the motives behind collecting the samples and some even openly expressed their concern that they feared that researchers would tell them that they could not drink their "special water" anymore. A fourth limitation with the collection of information for this assessment of non-conventional drinking water in the Northern River Basins Study was the relatively short amount of time spent in the communities. To obtain a better understanding of traditional ways of obtaining drinking water and the extent of use, more time should be spent in the communities to get to know the residents, to gain their trust, and to actually participate in the activities being studied. In this way, a deeper understanding of the non-conventional drinking water treatment practices of residents of the Northern River Basins Study can be attained. Another alternative may be to more actively involve resident Community Health Representatives in a study of this nature in the future.

6. REFERENCES

Alberta Agriculture. 1988. Dugouts for Farm Water Supplies. 2pp.

Alberta Environment. 1988. Standards and Guidelines for Municipal Water Supply, Wastewater, and Storm Drainage Facilities. Edmonton, Allberta.

American Public Health Association, American Water Works Association and Water Environment Federation. 1992. Standard Methods for the Examination of Water and Wastewater. 18th ed. Greenberg, A.E., L.S. Clesceri, and A.D. Eaton. Editors. Washington, D.C.

American Water Works Association (AWWA). 1990 Water Quality and Treatment: A Handbook of Community Wate Supplies. 4th ed. McGraw Hill Inc., New York. 455pp.

Babbie, E. 1992. The Practice of Social Research. 6th ed. Wadsworth Publishing Company. Belmont, Califormia. 493 pp.

Bill, Lea. 1995. Personal Communication. Telephone Interview. April 1995.

Bill, Lea. 1994. High Level, John D'Or, Fox Lake Field Trip. Personal Communication. November 1 to 4, 1994.

Bingham, A. 1994. Personal Communication. Northwestern Health Unit. High Level, Alberta. November 3, 1994.

Box, G.E.P., W.G. Hunter and J.S. Hunter. 1978. Statistics fpr Experimenters: An Introduction to Design, Data Analysis, and Model Building. John Wiley and Sons, Inc. New York. 653 pp.

Brocklehurst C. and Heinke G.W. 1985. The Effect Of Water Supply And Sanitation On Health On Indian Reserves in Manitoba. University of Toronto. Department of Civil Engineering. 15pp.

Brody, H. 1988. Maps and Dreams: Indians and the British Columbia Frontier. Douglas and McIntyre. Vancouver. 294pp.

Burris, Alan. 1986. Ozone. *Water Conditioning and Purification*. August 1986. 26-33.

Cairncross, S. and R. Feachem. 1993. Environmental Health Engineering in the Tropics: An Introductory Text. 2nd ed. John Wiley and Sons, New York. 295p.

Chalifoux, Rosie. 1995. Personal Communication. Atikameg, Alberta. February 28, 1995.

Courtoreille, John and Lena. 1994a. Personal Communication. Prairie River near Fort Chipewyan, Alberta. September 27, 1994.

Courtoreille, Willie. 1994b. Personal Communication. Fort Chipewyan, Alberta. September 27, 1994.

Craun, Gunther F. ed. Waterborne Diseases in the United States. CRC Press, Inc. Boca Raton, Florida. 1986. 295 pp.

Culotta, N.J. 1989. Home Water Treatment: What's the Use of Point-of Use? *Health and Environment Digest*. 3(6) July 1989.

Drinking Water Health Effects Task Force. 1989. Health Effects of Drinking Water Treatment Technologies. Lewis Publishers. Chealsea, Michigan. 146 pp.

The Editors. Emergency Disinfection of Drinking Water. *Dairy, Food and Environmental Sanitation*. August 1993. p 471.

Emde. K.M.E. 1995. Personal Communication. University of Alberta. Department of Civil Engineering. March 1995.

Emde, K.M.E., D.W. Smith and S.J. Stanley. 1994. Health Records Study for the Northern River Basins Project. Department of Civil Engineering, University of Alberta, Edmonton, Alberta. 30p.

Environmental Health Directorate. 1980. Assessing the Effectiveness of Small Filtration Systmes for Point-of-Use Disinfection of Drinking Water Supplies. 80-EHD-54. Health Protection Branch. Ottawa, Ontario. 43pp.

Environmental Health Directorate. 1973. Sanitation Manual for Isolated Regions. (5th Ed). Health Protection Branch. _ 64p.

Environmental Health Directorate Working Group. 1991. Reference Values for Canadian Populations. Draft. Health and Welfare Canada. Ottawa, Ontario. 36pp.

Epstein, R. 1982. Letters to the Editor. *Canadian Journal of Public Health*. 73: 433-434. [Original not seen; information taken from Fraser-Lee and Hessel, 1994]

Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health. 1993. Guidelines for Canadian Drinking Water Quality. 5th ed. Ottawa, Ontario. 24pp.

Flett, Scott. 1994. Personal Communication. Fort Chipewyan, Alberta. September 29, 1994.

Flett, Sonny and Lea Bill. 1994. Pesronal Communication. Northern River Basins Study Office. July, 1994.

Fogel, Doug. 1982. Waterborne Giardiasis and the role of the Health Inspector. Environmental Health Review. *The Journal of the Canadian Institute of Public Health Inspectors.* 26(2):26-29.

Fort MacKay Indian Band and Fort Chipewyan Cree and Chipewyan Indian Bands. 1988. The Northern Athabasca River Basin Study. A Native People's Perspective on Current and Historical Water Resource Issues. 29p

Fraser-Lee, N.J. and P.A. Hessel. 1994. Acute Respiratory Infections in the Canadian Native Indian Population: A Review. *Canadian Journal of Public Health*. May-June 1994. 85(3):197-200.

Gabler, R. and the Editors of Consumer Reports Books. 1988. Is Your Water Safe to Drink? Consumers Union, Mount Vernon. 390 pp.

Geldreich, E.E. 1991. Microbial Water Quality Concerns for Water Supply Use. *Environmental Toxicology and Water Quality*. 6:209-223[Original not seen; information taken from Emde et al., 1994]

Geldreich, E.E. and D.J. Reasoner. 1990. Home Treatment Devices and Water Quality in G. McFeters, ed. Drinking Water Microbiology. Springer-Verlag, New York. 502 pp.

Geldreich, E.E., R.H. Taylor, J.C. Blannon, and D.J. Reasoner. 1985. Bacterial Colonization of Point-Of-Use Water Treatment Devices. *Journal AWWA*. February 1985. 72-80

Getchell, D. 1994. Think before you drink. *Backpacker*. March 1994. 133-139.

Gibbens, David. 1995. Personal Communication. Prairie Farm Rehabilitation Administration. Agriculture and Agri-Food Canada. Edmonton, Alberta. February, 1995.

Grover, B. and D. Zussman. 1985. Safeguarding Canadian Drinking Waters. Environment Canada. Ottawa, Ontario. 97pp.

Health and Welfare Canada. 1991a. Water Treatment Devices - For Microbiological Purification of Water. Health Protection Branch Issues. 4pp.

Health and Welfare Canada. 1991b. Water Treatment Devices - For the Removal of Taste, Odour and Chemicals. Health Protection Branch Issues. 4pp.

Health and Welfare Canada. 1985a. Native Foods and Nutrition. An Illustrated Reference Resource. 95p.

Health and Welfare Canada. 1985b. Point-of-Use Water Treatment Devices. Educational Services, Health Protection Branch. Dispatch. No. 60. Winter 1985. 6pp.

Health and Welfare Canada. 1973. Sanitation Manual for Isolated Regions. 5th ed. Environmental Health Directorate. Health Protection Branch. 64 pp.

Health and Welfare Canada and Environment Canada.. 1991. "Wilderness Water: A Guide to Wilderness Drinking Water." Pamphlet.

Hemmelgarn, B., R. Klassen, B.F. Habbick, and A. Senthilselvan. 1993. Use of Gastrointestinal and Respiratory Illness Hospitalization Rates as Indicators of Different Social Influences. *Canadian Journal of Public Health*. 84(3): 136-138.

Huberman, Irwin. 1995. Personal Communication. Northern River Basins Study Office. Edmonton, Alberta. March 1995.

Jacobsen, N.A. 1994. Engineering to remove/inactivate parasite cysts. Giardia/Cryptosporidium seminar. Prince George, B.C. March 3, 1994.

Jackson, Brian. 1995. Personal Communication. Alberta Environment, Edmonton, Alberta. March, 1995.

Jakubowski, W et al. 1985. Roundtable: Waterborne Giardia: It's enough to make you sick. *Journal AWWA*. February, 1985. 14 p.

Laboucan, Dwayne. 1994a. Personal Communication. Fox Lake, Alberta. November 2, 1994.

Laboucan, Lesley. 1994b. Personal Communication. Fox Lake, Alberta. November 2, 1994.

Laboucan, Stanley and Susan. 1994c. Personal Communication. Fox Lake, Alberta. November 2, 1994.

Ladoucer, Raymond and Yvonne. 1994. Personal Communication. Fort Chipewyan, Alberta. September 29, 1994.

Lester, S.U. and Lipsett, B. 1988. Drinking Water Filters: What You Need to Know. Citizens Clearing House for Hazardous Wastes. Arlington, VA. 28 pp.

Letterman, R.D. 1994a. What Turbidity Measurements Can Tell Us. *Opflow*. 20(8):1-5 August 1994. Publication of AWWA.

Letterman, R.D. 1994b. Regs Change Use Of Turbidity Measurements. *Opflow*. 20(8):5-7 August 1994. Publication of AWWA.

Levallois, P. and Phaneuf, D. 1994. La Contamination de l'eau potable par les nitrates: analyse des risques à la santé. *Canadian Journal of Public Health*. 85(3):192-196.

Marten, George and Sammy. 1994a. Personal Communication. Fort Chipewyan. September 27, 1994

Marten, Stella. 1994b. Personal Communication. Fort Chipewyan, Alberta. September 27, 1994.

Marten, Terry. 1994c. Personal Communication. Fort Chipewyan, Alberta. September 27, 1994.

Mayo, A.W. and Mashauri, D.A. 1991. Rainwater harvesting for domestic use in Tanzania.. A Case Study: University of Dar Es Salaam Staff Houses. *Water International*. 16(1.):2-8.

McCabe, L.J. and Winton, E.F. 1990. Studies relating to water mineralization and health. *Journal AWWA,* 62(1):26-30.

McFeters, Gordon A. 1990. Editor. Drinking Water Microbiology: Progress and Recent Developments. Springer-Verlag. New York. 502 pp.

McJunkin, F.E. 1982. Water and Human Health. U.S. Agency for International Development, AID/DSAN-C-0063. Washington, D.C. 134p.

Montgomery, J.M. 1985. Water Treatment Principals and Design. John Wiley and Sons, Inc. New York. 696 pp.

Moore, A.C., B.L. Herwaldt, G.F. Craun, R.L. Calderon, A.K. Highsmith, D.D. Juranek. 1994. Waterborne Disease in the United States, 1991 and 1992. *Journal AWWA*. 86(2):87-99.

Mosby Medical Encyclopedia. 1986. 905 pp.

National Research Council (NRC). 1983. Risk Assessment in the Federal Government-Managing the Process. National Academy Press, Washington. D.C.

Northern River Basins Study. 1994. Status Report. January 1994. 22 pp.

Outdoor Retailer Editors. 1994. 1994 Mechanical Water Purification Guide. *Outdoor Retailer*. 1p.

Pontius, F.W. 1994. What you should know about Cryptosporidium. *Opflow*. 21(7):5-6.

Postl, B., M. Moffat and P. Sarsfield. 1987. Epidemiology and interventions for native Canadians. *Canadian Journal of Public Health*. 78:219-220. [Original not seen; information taken from Fraser-Lee and Hessel, (1994)]

Prince, D. S., S.J. Stanley and D.W. Smith. 1995. Preliminary Assessment of Drinking Water Quality in Small Communities in the Northern River Basins Study Area.. Northern River Basins Study. 8 pp.

Prince, D. S., S.J. Stanley and D.W. Smith. 1994. Review and Synthesis of Existing Information on Consmptive Use of Drinking Water and Available Drinking Water Quality Data. Northern River Basins Study. 17 pp.

Process Development Team. 1991. Evaluation of CT Values for Disinfection at Edmonton's Water Treatment Plants. Final Report. Water Plants Engineering Public Works, Cityof Edmonton.

Ramsom, Jim. 1995. Personal Communication. Assembly of First Nations. Ottawa, Ontario. February, 1995.

Reasoner, D.J., J.C. Blannon and E.E. Geldreich. 1987. Microbiological characteristics of third faucet point-of-use devices. *Journal AWWA*. October 1987. 79(10): 60-66.

Regunathan, P. and W.H. Beauman. 1987. Microbiological characteristics of point-of-use precoat carbon filters. *Journal AWWA*. October 1987. 79(10):67-75.

Rendtorff, R.C. and C.J. Holt. 1954. The experimental transmission of human intestinal protozoan parasites. IV. Attempts to transmit *Endamoeba coli* and *Giardia lamblia* by water. *Am J Hyg*. 60:327-328. [Original not seen; information taken from Rose et al., 1991]

Robertson, Will. 1995. Personal Communication. Health Canada. Ottawa, Ontario. January and March, 1995.

Robinson, B.A. and G.W. Heinke. 1990. The Effect of Municipal Services on Public Health in the Northwest Territories. Department of Municipal and Community Affairs. Government of the Northwest Territories. 81 pp.

Rose, J.B. 1993. Waterborne Pathogens: Assessing Health Risks. *Health Environment Digest*. 7(3):1-3.

Rose, J.B., C.P. Gerba and W. Jakubowski. 1991. Survey of potable water supplies for *Cryptosporidium* and *Giardia*. *Environ Sci Technol*. 25(8):1393-1400.

Rozelle, L T. 1987. Point-of-use and point-of-entry drinking water treatment. *Journal AWWA*. October 1987. 79(10): 53-59.

Schleifer, Elaine. 1995. Personal Communication. Telephone Interview. Atikameg, Alberta. February, 1995.

Sobsey, M.D., A.P. Dufour, C.P. Gerba, M.W. LeChevallier, and P. Payment. 1993. Using a conceptual framework for assessing risks to health from microbes in drinking water. *Journal AWWA*. 85(3):44-48.

St. Arnault, Lester. 1994. Personal Communication. John D'Or Prairie, Alberta. November 1 and 4, 1994.

St. Arnault, Lester. 1994. Personal Communication. Telephone interview. John D'Or Prairie, Alberta. December 7, 1994.

St. Arnault, Lester. 1995. Personal Communication. Telephone Interview. Garden River, Alberta. March, 1995

Tillett, H.E. 1993. Potential inaccuracy of microbiological counts from routine water samples. *Water Science Technology*. 27(3-4):15-19.

Tobin, R.S. 1987. Testing and Evaluating Point-of-Use Treatment Devices in Canada. *Journal AWWA*. October 1987. 79(10): 42-45.

Tobin, R.S. 1984. Water Treatment for the Home or Cottage. *Canadian Journal of Public Health*.. January/February 1984. 75:79-82.

Traditional Knowledge Component. 1995. Summary Results From the Document "How Our Knowledge Lives." Draft. Northern River Basins Study. 37pp.

Traditional Knowledge Component. 1994. Survey Instrument . Draft. Northern River Basins Study.

Troyan, J.J. and S.P. Hansen. 1989. Treatment of Microbial Contaminants in Potable Water Supplies: Technologies and Costs. Noyes Data Corporation. Park Ridge, New Jersey, U.S.A. 335 pp.

USEPA, 1991. Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources. Prepared by Malcolm Pirnie, Inc. for the Office of Drinking Water Science and Technology Branch. Copyright American Water Works Association, Denver, Colorado. 573 pp.

USEPA, 1974. Manual of Individual Water Supply Systems. Office of Water Programs Water Supply Division. EPA-430/9-74-007. 155 pp.

Warden, Wendy. 1994. Personal Communication. Fort Vermillion, Alberta. November 3, 1994.

Weller, G.R. and P. Manga. 1987. The politics of health in the circumpolar north. *Arctic Medical Research*. 46(2):52-63.

World Health Organization. 1993. Guidelines for Drinking Water Quality. Volume 1: Recommendations. 2nd ed. Geneva. 188p.

World Health Organization. 1978. Primary Health Care: Report of the International Conference on Primary Health Care. Alma-Ata, USSR. September 6-12, 1978.

APPENDIX A

Appendix A: Characteristics of Selected Waterborne Pathogens

ORGANISM	Pathogenicity			Vectors		Infectious Dose		Range of Symptoms	Potential Risk Groups
	None (*)	Oppor-tunisitic	Direct	Water	Food	Normal	Compromised or Sensitive		
BACTERIA									
Acinetobacter species	+	+		+		U	N, ND	2, 4	E, H, IS
Aeromonas hydrophila		+		+		U	N, ND	3, 4, 5, 6, 7	CI, E, D, H, IC, ID, IS, S, O
Alcaligenes species	+	+		+		U	N, ND	2	IC, IS, ID
Bacillus cereus		+	+	+	+	≈10^5/g food or water	ND	5	CI, E, H, IC, IS, ID, O, S
Campylobacter jejuni		+	+	+	+	<500cfu to >5000cfu	ND	5, 9 (in special cases)	CI, E, H, IC, IS, ID, O, S
Campylobacter coli		+	+	+	+	<500cfu	ND	5, 9 (in special cases)	CI, E, H, IC, IS, ID, O, S
Citrobacter freundii		+	+	+	+	U	N, ND	3, 4, 5, 6	CI, E, H, IC, IS, ID, O, S
Clostridium perfringens		+	+	+	+	≈10/g food or water	N, ND	1 (gas gangrene), 2, 5, 6	CI, E, H, IC, IS, ID, O, S
Enterobacter aerogenes	+	+		+	+	U	N, ND	3, 4, 5, 6, 7	CI, E, H, IC, IS, ID, O, S
Enterobacter agglomerans	+	+		+	+	U	N, ND	3, 4, 5, 6, 7	CI, E, H, IC, IS, ID, O, S
Enterobacter cloacae		+		+	+	U	N, ND	3, 4, 5, 6, 7	CI, E, H, IC, IS, ID, O, S
Escherichia coli		+	+	+	+	? to <10^8cfu by ingestion	N, ND	2, 3, 4, 5, 6, 7, 8	CI, E, H, IC, IS, ID, O, S
Flavobacterium species	+	+		+		U	N, ND	1, 2, 3, 4	CI, E, IC, IS, ID, S
Hafnia alvei	+	+		?	?	U	N, ND	3, 4, 5, 6, 7	CI, E, IC, IS, ID, S
Klebsiella oxytoca	+	+		+		U	N, ND	3, 4, 6	CI, E, IC, H, IS, ID, S
Klebsiella ozonae	+	+		+		U	N, ND	3, 4, 6	CI, E, IC, H, IS, ID, S
Klebsiella pneumophila		+	+	+	+	U	N, ND	3, 4, 6	CI, E, IC, H, IS, ID, S
Legionella pneumophila		+	+	+		U	N, ND	4	CI, E, IC, H, IS, ID, S
Legionella species		+	+	+		U	N, ND	4	CI, E, IC, H, IS, ID, S
Mycobacterium avium-intracellulare		+		+		U	N, ND	4, 8, 9	E, IC, IS, ID, S
Mycobacterium chelonae	+	+		+		U	N, ND	4, 8, 9	E, IC, IS, ID, S

ORGANISM	Pathogenicity			Vectors		Infectious Dose		Range of Symptoms	Potential Risk Groups
	None (*)	Oppor-tunisitic	Direct	Water	Food	Normal	Compromised or Sensitive		
Mycobacterium fortuitum	+	+		+		U	N, ND	4, 8, 9	E, IC, IS, ID, S
Mycobacterium gordonae	+	+		+		U	N, ND	4, 8, 9	E, IC, IS, ID, S
Moraxella species	+	+		+		U	N, ND	2	CI, E, H, IC, ID, IS
Proteus species	+	+		+		U	N, ND	3, 6, 7	IC, ID, IS, S
Pasteurella multicida	+	+		+		U	N, ND	3, 4, 5, 6	IC, ID, IS, S
Pseudomonas aeruginosa		+	+	+	+	U	N, ND	1, 2, 3, 4, 5, 6, 7	CI, E, H, IC, IS, ID, O, S
Pseudomonas cepecia	+	+		+		U	N, ND	1, 2, 3, 4, 5, 6, 7	CI, E, H, IC, IS, ID, O, S
Pseudomonas fluorescens	+	+		+	+	U	N, ND	1, 2, 3, 4, 5, 6, 7	CI, E, H, IC, IS, ID, O, S
Salmonella species		+	+	+	+	100 - 1000 by ingestion	N, ND	5, 8 (in special cases)	CI, E, H, IC, IS, ID, O, S
Serratia species	+	+		+		U	N, ND	1, 2, 3, 4, 7	CI, E, H, IC, IS, ID, O, S
Shigella species		+	+	+	+	180 by ingestion	N, ND	5	CI, E, H, IC, IS, ID, O, S
Staphylococcus aureus	+	+	+	+	+	U	N, ND	1, 2, 3, 4, 5, 6, 7	CI, E, H, IC, IS, ID, O, S
Staphylococcus epidermidis	+	+		+		U	N, ND	1, 2	IC, ID, IS
Streptococcus faecalis	+	+		+	+	U	N, ND	5, 6	CI, E, H, IC, IS, ID, S
Streptococcus fecium	+	+		+	+	U	N, ND	5, 6	CI, E, H, IC, IS, ID, S
Vibrio fluvalis		+				U	N, ND	2, 5, 7	CI, E, H, IC, IS, ID, S
Vibrio alginolyticus		+				U	N, ND	2	CI, E, H, IC, IS, ID, S
Yersinia enterocolitica		+	+	+	+	U	N, ND	5	CI, E, H, IC, ID, IS, S
AMOEBA									
Acanthamoeba species		+	+	+	?	U	N, ND	2, 8 (eg. meningitis)	CI, E, H, IC, ID, IS, S
Naegleria fowlerii		+	+	+	?	U	N, ND	8 (eg. meningitis)	CI, E, H, IC, ID, IS, S
FUNGI									
Aspergillus species	+	+		+	+	U	N, ND	1, 4, 8, 9 (eg. allergic response)	CI, E, H, IC, ID, IS, S
Cephalosporium species	+	+		+		U	N, ND	1, 4, 8, 9 (eg. allergic response)	CI, E, H, IC, ID, IS, S
Fusarium species	+	+		+		U	N, ND	1, 4, 8, 9 (eg. allergic response)	CI, E, H, IC, ID, IS, S
Penicillium species	+	+		+		U	N, ND	1, 4, 8, 9 (eg. allergic response)	CI, E, H, IC, ID, IS, S

ORGANISM	Pathogenicity			Vectors		Infectious Dose		Range of Symptoms	Potential Risk Groups
	None (*)	Oppor-tunisitic	Direct	Water	Food	Normal	Compromised or Sensitive		
Rhizopus species				+		U	N, ND	1, 4, 8, 9 (eg. allergic response)	CI, E, H, IC, ID, IS, S
VIRUSES									
Adenovirus		+		+		U	N, ND	2, 4, 5	CI, E, H, IC, ID, IS, S, O
Coxsackie virus		+		+		U	N, ND	2, 4, 5, 8, 9 (diabetes?)	CI, E, H, IC, ID, IS, S, O
Enterovirus		+		+		U	N, ND	2, 4, 5, 8	CI, E, H, IC, ID, IS, S, O
Hepatitis		+		+		U	N, ND	5, 8	CI, E, H, IC, ID, IS, S, O
Norwalk Virus		+		+		U	N, ND	5	CI, E, H, IC, ID, IS, S, O
Reovirus		+		+		U	N, ND	4, 5 (?)	CI, E, H, IC, ID, IS, S, O
Rotavirus		+		+		U	N, ND	5	CI, E, H, IC, ID, IS, S, O
PROTOZOA									
Cryptosporidium			+	+	?	1 cyst	1 cyst	5	CI, E, H, IC, ID, IS, S, O
Entamoeba histolytica			+	+	?	1 cyst	1 cyst	5	CI, E, H, IC, ID, IS, S, O
Giardia lamblia			+	+	?	1 cyst	1 cyst	5, 9 (eg. arthritis)	CI, E, H, IC, ID, IS, S, O

(Adapted from Emde et al., 1994)

1. * No documented pathogenicity for normally healthy persons
2. Risk Group Codes:

CI	Children and Infants	ID	Immunodeficient
E	Elderly	IS	Immumosuppressed
H	Healthy	S	Surgery
IC	Immunocompromised	O	Other (eg. previous illness, pregnancy etc)

3. Pathogenicity Codes:

U	Infectious dose for normally healthy persons unknown.
ND	Infectious dose for compromised persons not yet determined. In some cases the infectious dose may be as low as one organism .
N	Nosocomial infections documented.

4. Range of Symptoms Codes:

1	Skin/Hair infection	6.	Genitourinary infection
2	Eye/Ear infection	7.	Wound infections
3	Bacteremia/Septecemia	8.	Other types of infections (meningitis)
4	Pneumonia/Respiratory Illness	9	Chronic infection (asthma, arthritis etc)
5	Gastrointestinal infection		

APPENDIX B

Appendix B: Guidelines for Canadian Drinking Water Quality, 1993
Maximum Acceptable Concentrations

"Maximum Acceptable Concentrations have been established for certain substances that are known or suspected to cause adverse effects on health"(Health and Welfare Canada, 1993). MAC's are derived to protect health based on the assumption of lifelong consumption of the substance at the established guideline concentration.

Microbiological Parameters	MAC
Total Coliforms[1]	0 cfu/100mL
Turbidity[2]	1 NTU

Radiological Parameters[3]	MAC (Bq/L)
Cesium-137	50
Iodine-131	10
Radium-226	1
Strontium-90	10
Tritium	40 000

Chemical Parameters	MAC (mg/L)
aldicarb	0.009
aldrin + dieldrin	0.0007
azinphos-methyl	0.02
barium	1.0
bendiocarb	0.04
benzene	0.005
benzo(a)pyrene	0.00001
cadmium	0.005
carbaryl	0.09
carbofuran	0.09
carbon tetrachloride	0.005
chlordane	0.007
chlorpyrifos	0.09
chromium	0.05
cyanide	0.2
diazinon	0.02
dicamba	0.12
1,2-diclorobenzene	0.2

Chemical Parameters (con't)	MAC (mg/L)
1,4-dichlorobenzene	0.005
DDT + metabolites	0.03
dichloromethane	0.05
2,4-dichlorophenol	0.9
diclofop-methyl	0.009
dinoseb	0.01
diquat	0.07
diuron	0.15
flouride	1.5
heptachlor+heptachlor epoxide	0.003
lead[4]	0.01
lindane	0.004
malathion	0.19
mercury	0.001
mehoxychlor	0.9
metribuzin	0.08
monochlorobenzene	0.08
nitrate[5]	45.0
nitrolotriacetic acid	0.4
parathion	0.05
pentachlorophenol	0.06
selenium	0.01
2,3,4,6-tetrachlorophenol	0.1
triallate	0.23
trichloroethylene	0.05
2,4,6-trichlorophenol	0.005
2,4,5-T	0.28
trihalomethanes	0.1
uranium	0.1

[1] This MAC is considered in compliance if there is less than 10cfu/100mL (and none of these are fecal coliforms) and if no consecutive samples show the presence of total coliforms. Community systems must also not have more than one sample per day with the presence of coliforms and cannot have coliforms present more than 10% of the time. The water should be immediately resampled to confirm positive coliform counts if: (1) the MAC is exceeded, (2) the total coliform background plate count is greater than 200 cfu/100mL or (3) the heterotrophic plate count is greater than 500cfu/mL.

[2] 5 NTU is permitted if it can be shown that disinfection is not compromised.

[3] Radiological guidelines are currently under review.

[4] At the point of consumption.

[5] Equivalent to 10mg/L nitrate as nitrogen.

Guidelines for Canadian Drinking Water Quality, 1993
Interim Maximum Acceptable Concentrations

Interim Maximum Acceptable Concentrations (IMAC) are set for substances that are assumed to have an adverse effect on health but for which there is insufficient toxicological data to set an MAC with reasonable certainty. Larger safety factors have been employed to compensate for the uncertainties for these substances.

Chemical Parameters	IMAC (mg/L
arsenic	0.025
atrazine	0.06
boron	5.0
bromoxynil	0.005
cyanazine	0.01
1,2-dichloroethane	0.005
2,4-D	0.1
dimethoate	0.02
glyphosate	0.28

Chemical Parameters (con't)	IMAC (mg/L
metolachlor	0.05
paraquat	0.01
phorate	0.002
picloram	0.19
simazine	0.01
temephos	0.28
terbufos	0.001
trifluralin	0.045

Guidelines for Canadian Drinking Water Quality, 1993
Aesthetic Objectives

Aesthetic Objectives are applied to parameters that affect the acceptablility of the water by consumers and so that a good quality of water can still be supplied. If the concentration is well above and aesthetic objective, there is a possibility of a health hazard. The AO parameters marked with an asterisk (*) also have assigned MAC guidelines.

Physical Parameters	AO
colour	≤15 TCU
odour	inoffensive
pH	6.5-8.5 units
taste	inoffensive
temperature	15°C
total dissolved solids (TDS)	≤500 mg/L
turbidity[1]	≤5NTU

Chemical Parameters	AO(mg/L)
chloride	≤250
copper[1]	≤1.0
1.2-dichlorobenzene *	≤0.003
1,4-dichlorobenzene *	≤0.001
2,4-dichlorophenol *	≤0.0003

Chemical Parameters (con't)	AO(mg/L)
ethylbenzene	≤0.0024
iron	≤0.3
manganese	≤0.05
monochlorobenzene *	≤0.03
pentachlorophenol *	≤0.03
sodium	≤200
sulphate	≤500
sulphide (as H_2S)	≤0.05
2,3,4,6-tetrachlorophenol *	≤0.001
toluene	≤0.024
2,4,6-trichlorophenol *	≤0.002
2,4,5-T *	≤0.02
total xylenes	≤0.3
zinc[1]	≤5.0

[1] At the point of consumption

APPENDIX C

Appendix C: Analysis of Water Samples
Treated Water Samples

Table C-1. Treated Water Physical and Chemical Parameters

Sample	Date	pH	Turbidity NTU	Odour subjective	Conduct umhos/cm	Colour TCU	Ammonia $mgNH_3$-N/L	Free Cl_2 mg/L	Total Cl_2 mg/L	TOC mg/L
John D'Or Cistern	Nov 4/94	8.0	0.3	chlorine	500	15	0.013	0.02*	0.05*	10.7
Atikameg Health Unit	Feb 28/95	6.81	0.76	chlorine	430	40	0.01	1	2	9.65
Atikameg POU Treatment Filter‡	Feb 28/95	6.86	0.4	None	375	30	0.01	0.05	0.27	2.64

Table C-2. Treated Water Metals Analysis

Sample	Date	B ug/L	As ug/L	Ba ug/L	Cd ug/L	Cr ug/L	Cu ug/L	Fe mg/L	Mn ug/L	Pb ug/L	Hg ug/L	Zn ug/L
1993 Canadian Drinking Water Quality Guideline		IMAC 5000	IMAC 25	MAC 1000	MAC 5	MAC 50	AO ≤1000	AO ≤0.3	AO ≤50	MAC 10	MAC 1	AO ≤5000
John D'Or Cistern	Nov 4/94	30	<1	46	<1	<1	16	0.6	13	1	1	20
Atikameg Health Unit	Feb 28/95	<1	<1	24	<1	<1	88	11	11	<1	<1	<1
Atikameg POU Treatment Filter	Feb 28/95	<1	<1	22	<1	<1	7	10	15	<1	<1	<1

Table C-3. Treated Water Microbial Parameters

Sample	Date	TC cfu/100mL	FC cfu/100mL	FS cfu/100mL	Klebsiella cfu/100mL	Yeasts cfu/100mL	Molds cfu/100mL	48hr HPC cfu/mL	7d HPC cfu/mL
John D'Or Cistern	Nov 4/94	<1	<1	<1	<1	1.0×10^3	8.4×10^2	3.6×10^1	3.6×10^1
Atikameg Health Unit	Feb 28/95	<1	<1	<1	<1	<1	<1	<1	<1
Atikameg POU Treatment Filter	Feb 28/95	9.0×10^0	<1	<1	<1	1.3×10^3	2.0×10^2	3.3×10^1	3.3×10^1

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* Suspect data because researchers were unable to perform free and total chlorine analysis at the site of collection and therefore there was a lag period before these parameters could be tested.

‡ Not considered to be Conventionally Treated Drinking Water because this water has been further treated at the point of use with an indivually owned treatment device.

Surface Water Samples

Table C-4. Surface Water Physical and Chemical Analysis

Sample	**Date**	**Temp** °C	**pH**	**Turbidity** NTU	**Odour** subjective	**Conductivity** umhos/cm	**Colour** TCU	**Ammonia** $mgNH_3$-N/L	**TOC** mg/L
Sand Point	Sept 27 / 94	-	7.9	16	none	85	20	0.012	-
Old Fort Point	Sept 27 / 94	10	8.2	41	muddy	300	65	0.117	6.7
Keane River	Sept 27 / 94	9	7.7	11	muddy	125	35	0.05	5.0
Jackfish Village	Sept 27 / 94	12	8.1	7.4	none	330	52	0.043	5.9
Prairie River	Sept 28 / 94	8.5	8.1	>100	muddy	560	280	0.4	19.7
Quatre Forches	Sept 28 / 94	10	8.1	17	chemical	295	90	0.025	5.6
Lawrence Creek	Nov 1 / 94	0	7.8	27.5	wood-none	1780	40	0.043	29.0
Lawrence River	Nov 1 / 94	0.5	8	5.5	grass-none	700	125	0.027	15.7
Birch Creek	Nov 1 / 94	1	7.5	19	salt-sulphur	1250	55	0.075	11.4
Little Red River	Nov 2 / 94	0	7.3	3	none	350	235	0	23.2
Wentzel River	Nov 4 / 94	0.5	7.9	5	swamp	570	90	0.075	17.3

Table C-5. Surface Water Metals Analysis

Sample	**Date**	**B** ug/L	**As** ug/L	**Ba** ug/L	**Cd** ug/L	**Cr** ug/L	**Cu** ug/L	**Fe** mg/L	**Mn** ug/L	**Pb** ug/L	**Hg** ug/L	**Zn** ug/L
1993 Canadian Drinking Water Quality Guideline		IMAC 5000	IMAC 25	MAC 1000	MAC 5	MAC 50	AO ≤1000	AO ≤0.3	AO ≤50	MAC 10	MAC 1	AO ≤5000
Sand Point	Sept 27/94	<1	1	14	<1	<1	<1	0.4	22	<1	<1	4
Old Fort Point	Sept 27/94	5	2	54	<1	<1	2	1.2	67	2	<1	5
Keane River	Sept 27/94	<1	<1	12	<1	<1	<1	0.7	40	1	<1	2
Jackfish Village	Sept 27/94	6	1	47	<1	<1	2	0.3	24	<1	<1	1
Prairie River	Sept 28/94	55	4	95	<1	<1	12	5.2	270	4	<1	23
Quatre Forches	Sept 28/94	5	1	49	<1	<1	2	0.7	28	<1	<1	3
Lawrence Creek	Nov 1/94	110	6	63	<1	<1	23	6.8	2400	5	2	32
Lawrence River	Nov 1/94	53	1	56	<1	<1	6	1.0	21	<1	4	1
Birch Creek	Nov 1/94	150	1	28	<1	<1	10	1.5	810	1	1	16
Little Red River	Nov 2/94	25	1	33	<1	<1	6	1.0	21	<1	4	1
Wentzel River	Nov 4/94	36	<1	60	<1	<1	3	<1	22	<1	<1	3

Table C-6. Surface Water Microbial Parameters

Sample	**Date**	**TC** cfu/100mL	**FC** cfu/100mL	**FS** cfu/100mL	**Klebsiella** cfu/100mL	**Yeasts** cfu/100mL	**Molds** cfu/100mL	**48hr HPC** cfu/mL	**7d HPC** cfu/mL
Sand Point	Sept 27/94	1.0×10^{0}	<1	2.0×10^{0}	5.0×10^{0}	1.9×10^{3}	1.6×10^{2}	4.0×10^{0}	2.6×10^{2}
Old Fort Point	Sept 27/94	TNTC	<1	1.4×10^{1}	?	9.2×10^{3}	3.0×10^{3}	1.2×10^{2}	2.0×10^{3}
Keane River	Sept 27/94	TNTC	<1	3.3×10^{1}	<1	3.6×10^{4}	3.4×10^{3}	3.6×10^{2}	1.6×10^{3}
Jackfish Village	Sept 27/94	6.0×10^{0}	<1	5.0×10^{0}	<1	2.2×10^{3}	1.4×10^{3}	5.0×10^{1}	2.2×10^{2}
Prairie River	Sept 28/94	3.0×10^{0}	<1	5.9×10^{1}	Confluent	1.5×10^{4}	1.4×10^{3}	5.8×10^{1}	4.7×10^{2}
Quatre Forches	Sept 28/94	1.0×10^{1}	<1	1.0×10^{0}	<1	9.1×10^{3}	1.6×10^{3}	2.3×10^{1}	5.7×10^{2}
Lawrence Creek	Nov 1/94	7.0×10^{0}	<1	6.0×10^{0}	<1	1.3×10^{3}	4.2×10^{3}	4.4×10^{1}	2.8×10^{3}
Lawrence River	Nov 1/94	2.4×10^{1}	<1	3.0×10^{0}	<1	3.6×10^{3}	2.1×10^{3}	2.3×10^{1}	2.0×10^{3}
Birch Creek	Nov 1/94	4.2×10^{1}	<1	2.1×10^{1}	<1	6.1×10^{4}	4.4×10^{3}	5.4×10^{1}	5.3×10^{3}
Little Red River	Nov 2/94	6.5×10^{1}	2.0×10^{0}	<1	<1	1.5×10^{3}	2.0×10^{3}	5.0×10^{1}	3.6×10^{2}
Wentzel River	Nov 4/94	2.2×10^{1}	2.0×10^{0}	<1	<1	7.3×10^{3}	5.6×10^{3}	1.4×10^{2}	1.1×10^{3}

Ground Water Samples

Table C-7. Groundwater Physical and Chemical Parameters

Sample	Date	Temp °C	pH	Turbidity NTU	Odour subjective	Conductivity umhos/cm	Colour TCU	Ammonia $mgNH_3$-N/L	TOC mg/L
Sacred Spring	Nov 1 / 94	1.5	7.8	1	musty-bullrush	3400	5	0.012	20.7
Fox Lake Well	Nov 2 / 94	7.5	7.4	13	iron	500	5	0.31	5.4

Table C-8. Groundwater Metals Analysis

Sample	Date	B ug/L	As ug/L	Ba ug/L	Cd ug/L	Cr ug/L	Cu ug/L	Fe mg/L	Mn ug/L	Pb ug/L	Hg ug/L	Zn ug/L
1993 Canadian Drinking Water Quality Guideline		IMAC 5000	IMAC 25	MAC 1000	MAC 5	MAC 50	AO ≤1000	AO ≤0.3	AO ≤50	MAC 10	MAC 1	AO ≤5000
Sacred Spring	Nov 1 / 94	360	2	43	<1	<1	36	<1	15	<1	2	6
Fox Lake Well	Nov 2 / 94	23	5	160	<1	<1	<1	1.4	210	<1	<1	580

Table C-9. Groundwater Microbial Parameters

Sample	Date	TC cfu/100mL	FC cfu/100mL	FS cfu/100mL	Klebsiella cfu/100mL	Yeasts cfu/100mL	Molds cfu/100mL	48hr HPC cfu/mL	7d HPC cfu/mL
Sacred Spring	Nov 1 / 94	<1	<1	<1	<1	1.8×10^3	3.0×10^2	1.7×10^1	1.7×10^2
Fox Lake Well	Nov 2 / 94	<1	<1	<1	<1	1.0×10^2	3.4×10^2	2.9×10^1	8.9×10^1

Snow Water Samples

Table C-10. Snow Water Physical and Chemical Parameters

Sample	Date	Temp °C	pH	Turbidity NTU	Odour subjective	Conductivity umhos/cm	Colour TCU	Ammonia $mgNH_3$-N/L	TOC mg/L
Atikameg Snow	Feb 28 / 95	22	6.35	5.24	None	50	65	0.25	4.2
Twin Lakes Snow	Feb 28 / 95	24	6.03	7.55	Rocky	50	45	0.105	3.3

Table C-11. Snow Water Metals Analysis

Sample	Date	B ug/L	As ug/L	Ba ug/L	Cd ug/L	Cr ug/L	Cu ug/L	Fe mg/L	Mn ug/L	Pb ug/L	Hg ug/L	Zn ug/L
1993 Canadian Drinking Water Quality Guideline		IMAC 5000	IMAC 25	MAC 1000	MAC 5	MAC 50	AO ≤1000	AO ≤0.3	AO ≤50	MAC 10	MAC 1	AO ≤5000
Atikameg Snow	Feb 28 / 9	<1	<1	1	1	<1	<1	10	6	1	<1	6
Twin Lakes Snow	Feb 28 / 9	<1	<1	<1	<1	<1	<1	9	8	<1	<1	<1

TableC-12. Snow Water Microbial Parameters

Sample	Date	TC cfu/100mL	FC cfu/100mL	FS cfu/100mL	Klebsiella cfu/100mL	Yeasts cfu/100mL	Molds cfu/100mL	48hr HPC cfu/mL	7d HPC cfu/mL
Atikameg Snow	Feb 28/95	5.8×10^2	<1	<1	<1	4.1×10^3	2.8×10^3	1.2×10^2	1.5×10^2
Twin Lakes Snow	Feb 28/95	1.0×10^0	<1	<1	<1	4.6×10^3	4.6×10^3	1.3×10^2	1.2×10^2

Bottled Water Samples

Table C-13. Bottled Water Physical and Chemical Parameters

Sample	Date	Temp °C	pH	Turbidity NTU	Odour subjective	Conductivity umhos/cm	Colour TCU	Ammonia $mgNH_3$-N/L	TOC mg/L
Bottled Ozonated Water	Feb 28/95	4	6.47	0.21	sweet "rain"	150	33	0.01	1.22
Bottled Spring Water	Feb 28/95	17	6.33	0.13	plastic/ none	30	30	0.01	0.67

TableC-14. Bottled Water Metals Analysis

Sample	Date	B ug/L	As ug/L	Ba ug/L	Cd ug/L	Cr ug/L	Cu ug/L	Fe mg/L	Mn ug/L	Pb ug/L	Hg ug/L	Zn ug/L
1993 Canadian Drinking Water Quality Guideline		IMAC 5000	IMAC 25	MAC 1000	MAC 5	MAC 50	AO ≤1000	AO ≤0.3	AO ≤50	MAC 10	MAC 1	AO ≤5000
Bottled Ozonated Water	Feb 28/95	<1	<1	6	<1	<1	<1	7	4	<1	<1	<1
Bottled Spring Water	Feb 28/95	<1	<1	<1	<1	<1	<1	11	4	<1	<1	<1

Table C-15. Bottled Water Microbial Parameters

Sample	Date	TC cfu/100mL	FC cfu/100mL	FS cfu/100mL	Klebsiella cfu/100mL	Yeasts cfu/100mL	Molds cfu/100mL	48hr HPC cfu/mL	7d HPC cfu/mL
Bottled Ozonated Water	Feb 28/95	<1	<1	<1	<1	<1	<1	8.9×10^2	5.6×10^3
Bottled Spring Water	Feb 28/95	<1	<1	<1	<1	3.9×10^4	2.0×10^3	1.7×10^3	4.6×10^3

Trihalomethane Formation Potential Analysis

Table C-16. THM Formation Potential Analysis.

Location	TOC (mg/L)	Chloroform (ug/L)			Bromodichloromethane (ug/L)			Dibromochloromethane (ug/L)			Bromoform (ug/L)		
	RAW	RAW	3:1	6:1	RAW	3:1	6:1	RAW	3:1	6:1	RAW	3:1	6:1
Old Fort	6.7	6	570	650	1.3	22	28	BDL	0.6	1.6	BDL	1.1	0.2
Keane River	5.0	14	310	-	BDL	38	-	BDL	3.1	-	BDL	0.3	-
Jackfish Village	5.9	4	503	-	BDL	13	-	BDL	0.2	-	BDL	1.4	-
Prairie River	19.7	4	1414	-	0.6	74	-	BDL	4.8	-	BDL	0.2	-
Quatre Forches	5.6	7	440	541	BDL	14	16	BDL	1.0	1.1	BDL	BDL	BDL
Laurence Creek	29.0	7	1770	-	6.2	210	-	0.2	28.0	-	BDL	1.3	-
Laurence River	15.7	4	1372	-	1.4	26	-	BDL	0.2	-	BDL	0.2	-
Birch Creek	11.4	3	879	-	1.4	67	-	BDL	3.5	-	BDL	0.2	-
Sacred Spring	20.7	2	1237	-	1.6	202	-	BDL	46.0	-	BDL	2.4	-
Little Red River	23.2	5	2383	2837	1.9	25	27	BDL	0.6	0.9	BDL	0.3	0.4
Fox Lake Well	5.4	3	129	-	BDL	8	-	BDL	2.0	-	BDL	BDL	-
John D'Or Cistern	10.7	108	722	-	5.5	15	-	BDL	1.3	-	BDL	0.1	-
Wentzel River	17.3	1	1492	1707	2.8	35	40	BDL	0.8	0.3	BDL	0.2	0.3

Notes:
1.The 3:1 and 6:1 headings are the Chorine:TOC ratios used for chlorine dosing of the samples.
2. BDL = Below Detection Limit

For the Chlorine Dose, initially, a Chlorine:TOC ration of 3:1 was used as was suggested in the literature. However, after the 7-day reaction period required for THM Potential analyses, there was no residual free chlorine left in the sample. Therefore, it was decided to try the same experiment a second time with a Chlorine:TOC ratio of 6:1 for four of the samples. Once again, there was no residual chlorine left at the completion of the seven day reaction period, so the results are not completely accurate. Nonetheless, trends in the THM potential analysis are evident and therefore, the results can still be interpreted.

APPENDIX D

APPENDIX D: RESULTS FROM PORTABLE FILTER TESTING
TURBIDITY ANALYSIS

Table D-1. Average Turbidity(NTU)

Sample	Volume Filtered (L)							
	1	4	6	8	10	17	18	20
Influent	33.3	30.3	30.3	25.9	25.9	31.1	31.1	31.1
Plastic	1.8	1.8	3.9	2.7	2.9	-	-	3.6
Carbon	1.3	1.9	3.1	2.0	2.1	-	-	3.1
Ceramic	0.94	0.54	0.38	0.23	0.34	0.19	0.70	0.56

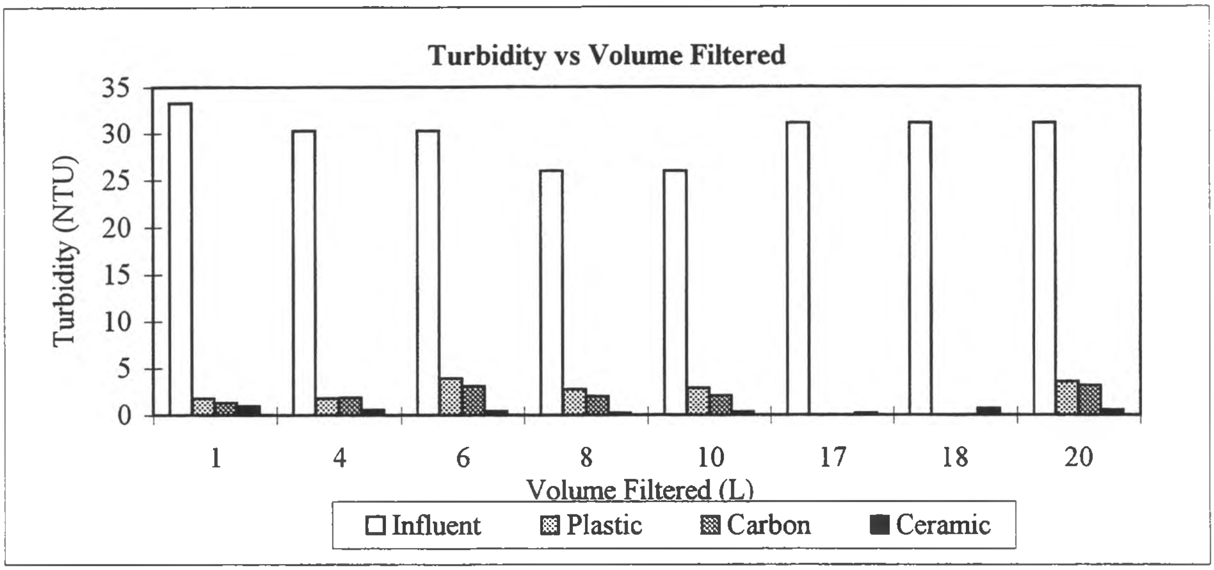

Figure D-1. Average Turbidity vs Volume

Table D-2. Percent Turbidity Reduction.

Sample	Volume Filtered (L)					
	1	4	6	8	10	20
Plastic	94.6	94.2	87.0	89.3	88.6	88.2
Carbon	96.2	93.8	89.9	92.3	92.0	89.8
Ceramic	97.2	98.2	98.7	99.1	98.7	98.2

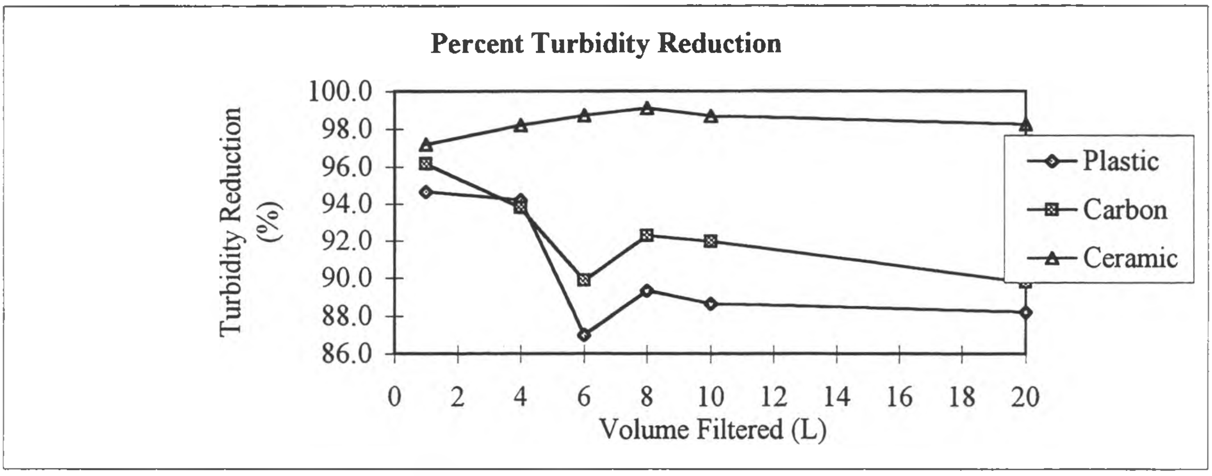

Figure D-2. Percent Turbidity Reduction vs Volume Filtered.

MICROBIAL ANALYSIS

Table D-3. Average E.coli Concentration (cfu/100mL)

Sample	Volume Filtered (L)					
	1	4	6	8	10	20
Influent	5.0E+6	4.1E+6	6.5E+6	5.8E+6	5.8E+6	6.7E+6
Plastic	TNTC	TNTC	4.3E+6	2.0E+6	2.2E+6	3.8E+6
Carbon	2.3E+2	1.9E+3	1.3E+5	1.0E+6	7.8E+5	1.5E+6
Ceramic	O	O	O	O	O	O

(TNTC = Too Numerous to Count)

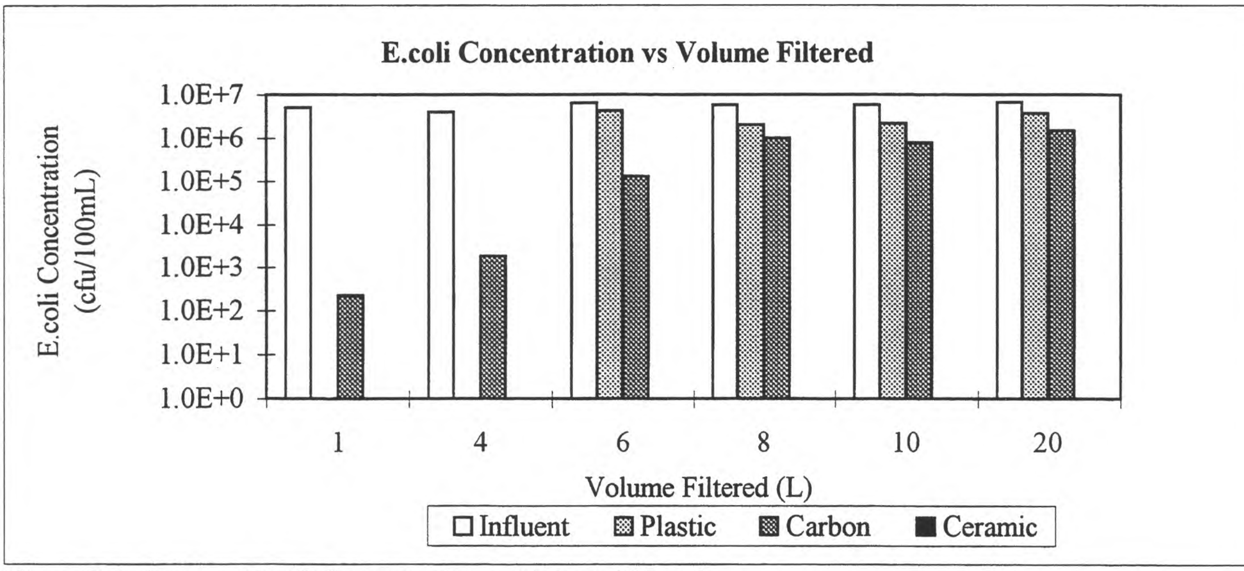

Figure D-3. Average E.coli Concentration vs Volume Filtered.

Table D-4. Percent E. coli Reduction.

Sample	Volume Filtered (L)					
	1	4	6	8	10	20
Plastic	-	-	40.3	67.4	64.3	54.5
Carbon	99.995	100.0	98.2	82.6	86.3	83.2
Ceramic	100	100	100	100	100	100

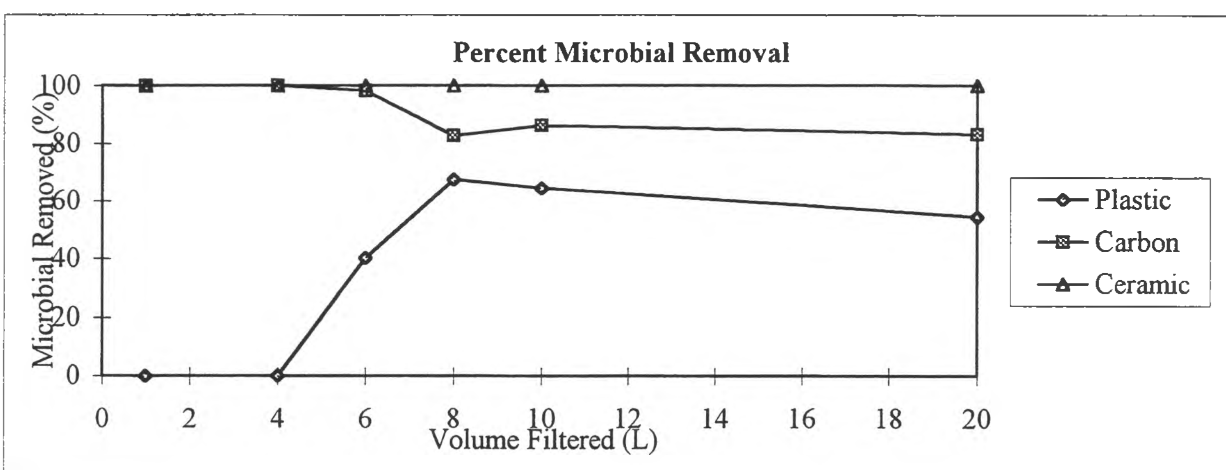

Figure D-4. Percent E.coli Reduction vs. Volume Filtered.

PARTICLE ANALYSIS

Table D-5. Average Particle Count per mL (1 to 2 micron range)

Sample	Volume Filtered (L)							
	1	4	6	8	10	17	18	20
Influent	1240573	1240573	1112055	1072636	1072636	1198350	1198350	1165879
Plastic	38957	38738	143762	105026	89436	-	-	107467
Carbon	41425	39866	46863	23674	29574	-	-	32013
Ceramic	14077	3035	1022	344	689	382	4428	135

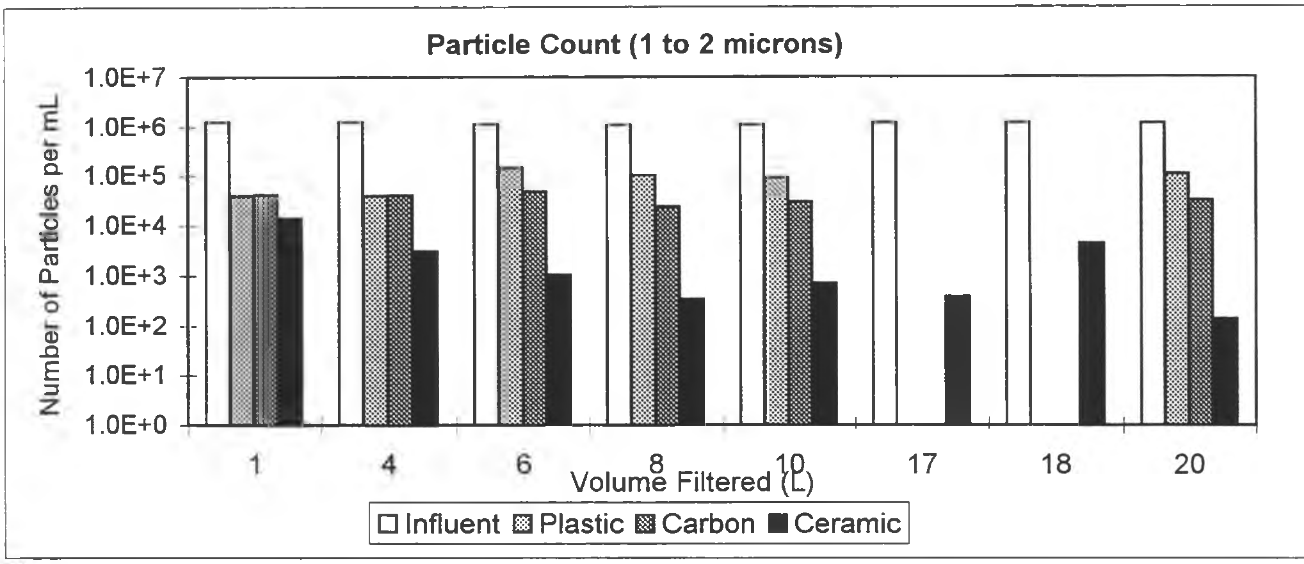

Figure D-5. Average Particle Count vs Volume Filtered (1 to 2 micron range)

Table D-6. Percent Particle Reduction for 1 to 2 micron range.

Sample	Volume Filtered (L)					
	1	4	6	8	10	20
Plastic	96.86	96.88	88.85	90.86	92.22	90.11
Carbon	96.66	96.79	95.41	97.87	97.34	97.36
Ceramic	98.87	99.76	99.90	99.96	99.93	99.99

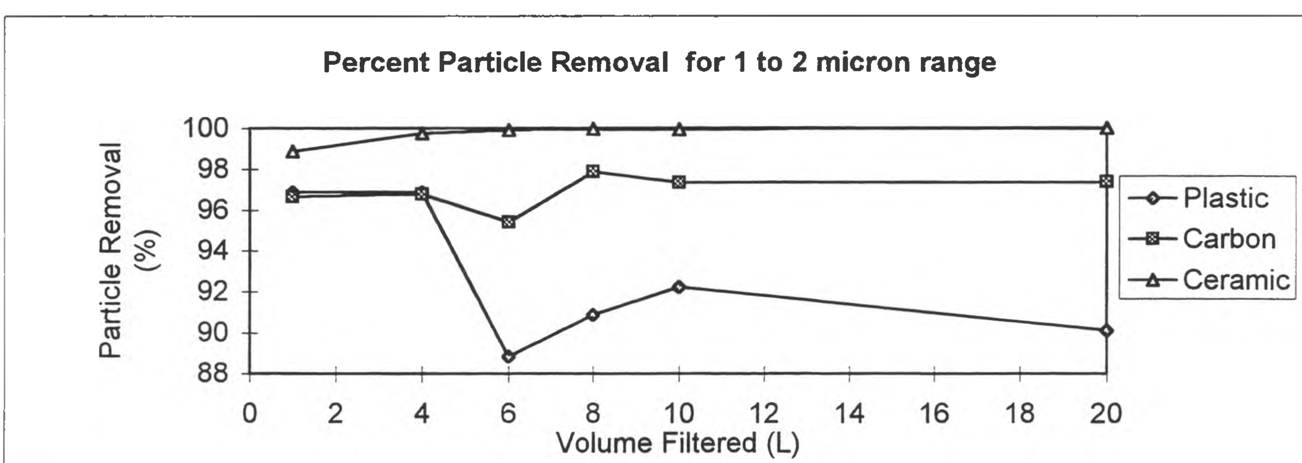

Figure D-6. Percent Particle Reduction vs. Volume Filtered for 1 to 2 micron range

PARTICLE ANALYSIS

Table D-7. Average Particle Count per mL (2 to 3 micron range)

Sample	Volume Filtered (L)							
	1	4	6	8	10	17	18	20
Influent	123670	123670	114728	116682	116682	122709	122709	117082
Plastic	761	480	1689	845	832	-	-	1094
Carbon	1880	1565	852	441	502	-	-	384
Ceramic	301	145	70	12	45	21	337	6

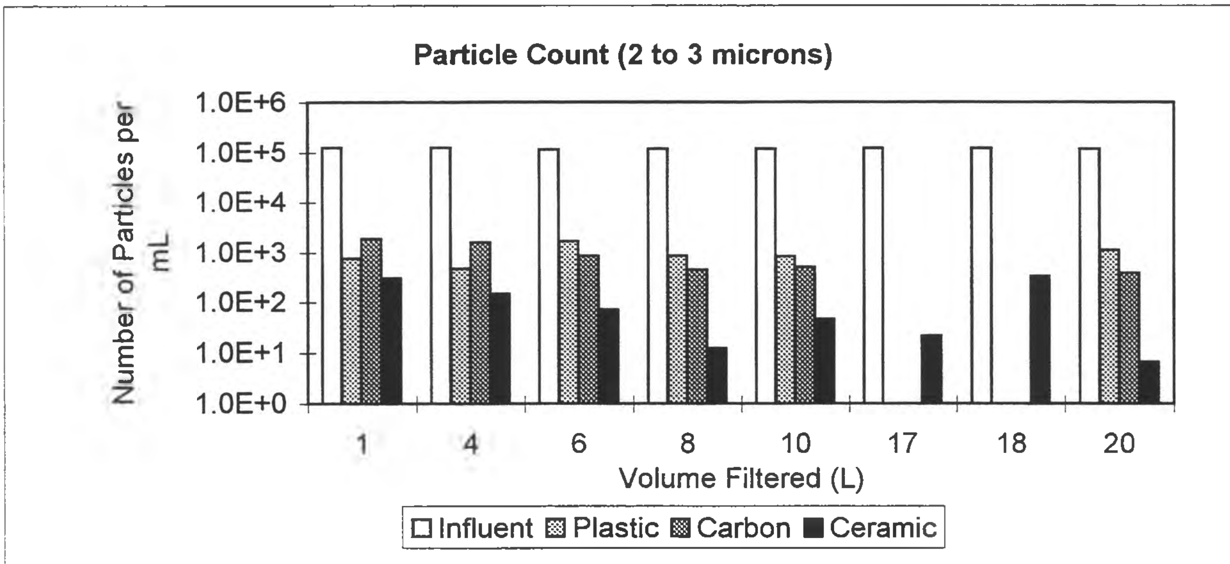

Figure D-7. Average Particle Count vs Volume Filtered (2 to 3 micron range)

Table D-8. Percent Particle Reduction for 2 to 3 micron range.

Sample	Volume Filtered (L)					
	1	4	6	8	10	20
Plastic	99.38	99.61	98.75	99.32	99.33	98.97
Carbon	98.48	98.73	99.19	99.64	99.59	99.69
Ceramic	99.76	99.88	99.93	99.99	99.96	99.99

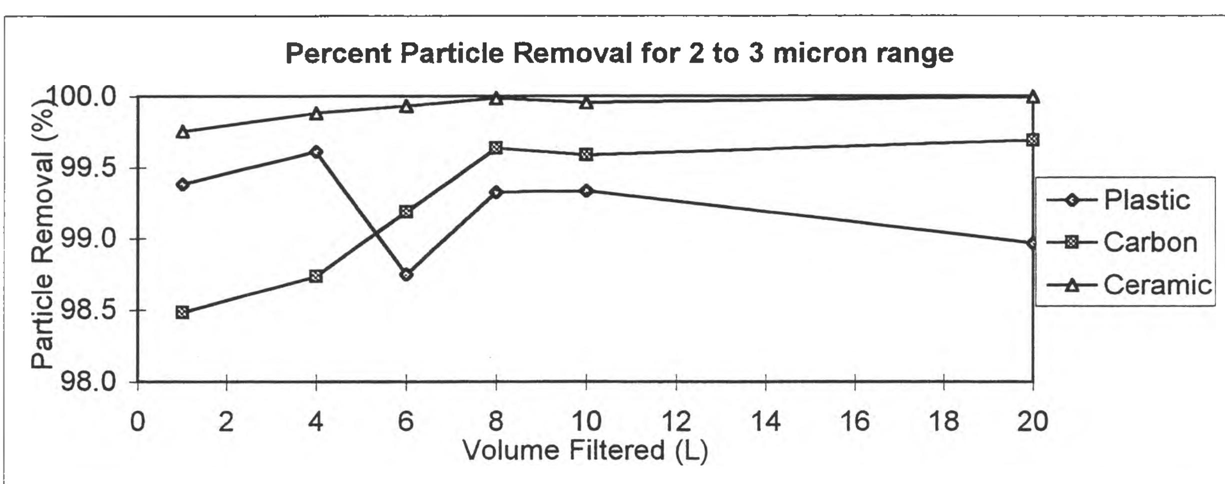

Figure D-8. Percent Particle Reduction vs. Volume Filtered for 2 to 3 micron range

PARTICLE ANALYSIS

Table D-9. Average Particle Count per mL (3 to 4 micron range)

Sample	Volume Filtered (L)							
	1	4	6	8	10	17	18	20
Influent	87166	87166	80870	86214	86214	88268	88268	84199
Plastic	478	306	883	366	367	-	-	387
Carbon	984	852	454	253	283	-	-	268
Ceramic	198	92	50	8	30	13	220	4

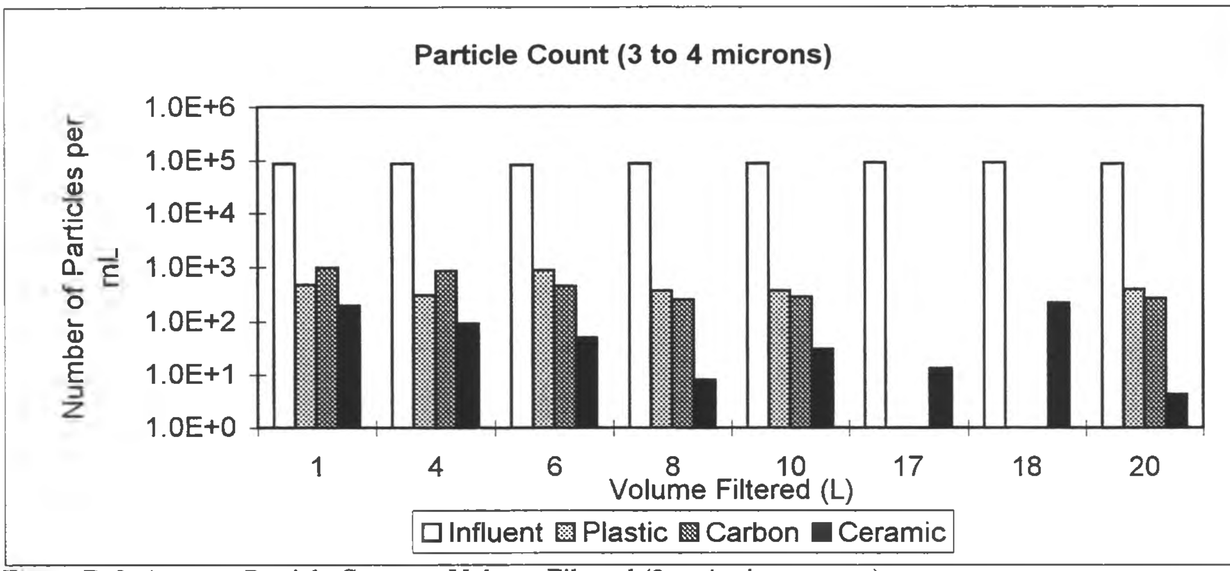

Figure D-9. Average Particle Count vs Volume Filtered (3 to 4 micron range)

Table D-10. Percent Particle Reduction for 3 to 4 micron range.

Sample	Volume Filtered (L)					
	1	4	6	8	10	20
Plastic	99.45	99.65	99.07	99.61	99.61	99.49
Carbon	98.87	99.02	99.38	99.72	99.68	99.70
Ceramic	99.77	99.89	99.93	99.99	99.96	100.00

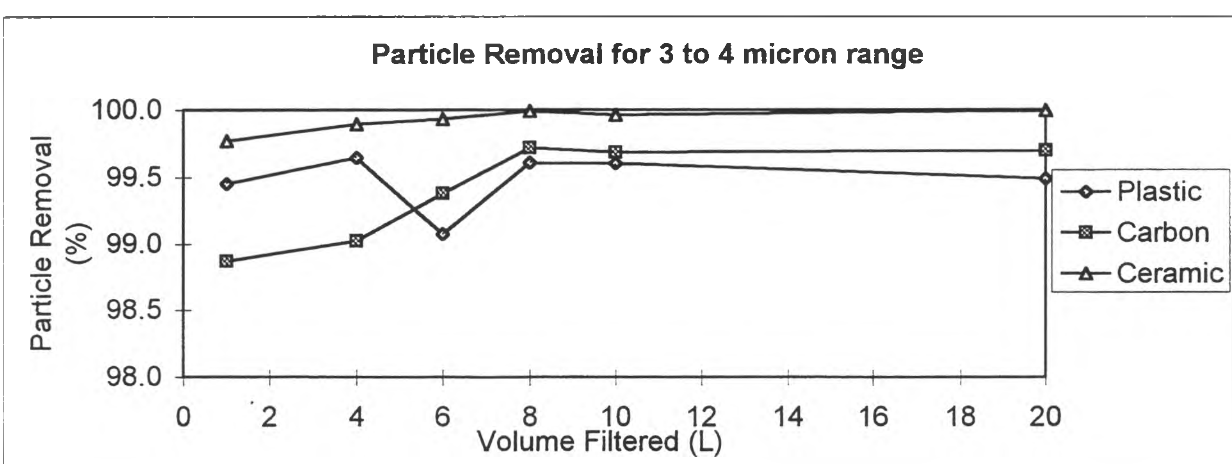

Figure D-10 Percent Particle Reduction vs. Volume Filtered for 3 to 4 micron range

PARTICLE ANALYSIS

Table D-11. Average Particle Count per mL (4 to 5 micron range)

Sample	Volume Filtered (L)							
	1	4	6	8	10	17	18	20
Influent	76722	76722	71560	78640	78640	82370	82370	78793
Plastic	389	265	762	259	288	-	-	238
Carbon	654	626	318	180	223	-	-	241
Ceramic	176	78	50	7	29	10	193	4

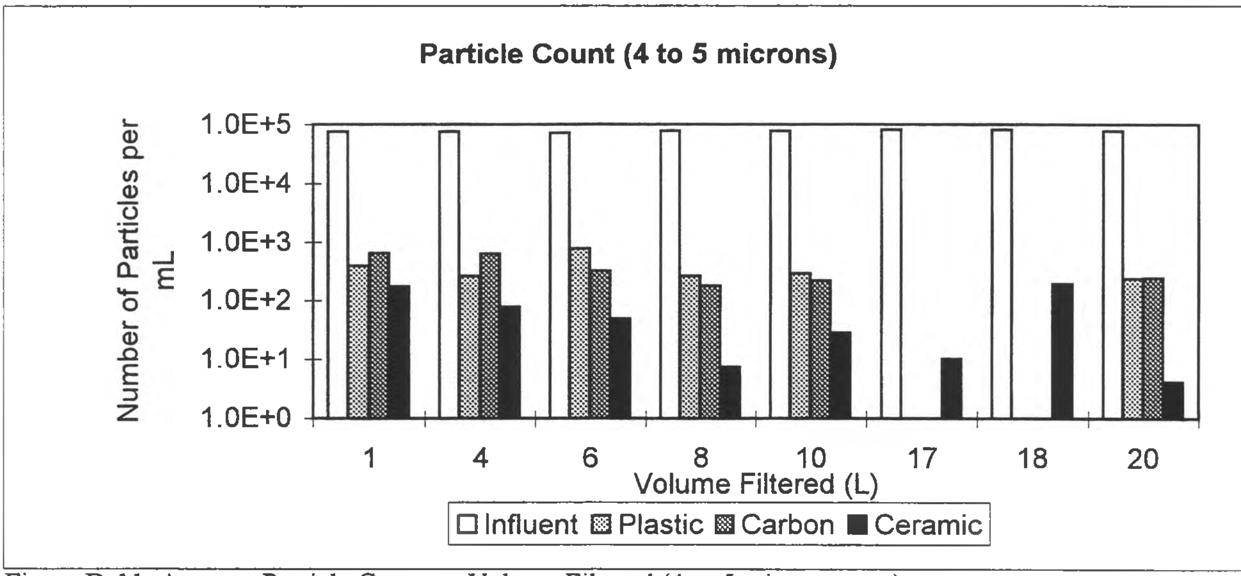

Figure D-11. Average Particle Count vs Volume Filtered (4 to 5 micron range)

Table D-12. Percent Particle Reduction for 4 to 5 micron range.

Sample	Volume Filtered (L)					
	1	4	6	8	10	20
Plastic	99.49	99.65	99.08	99.70	99.66	99.67
Carbon	99.15	99.18	99.51	99.78	99.72	99.71
Ceramic	99.77	99.90	99.93	99.99	99.96	99.99

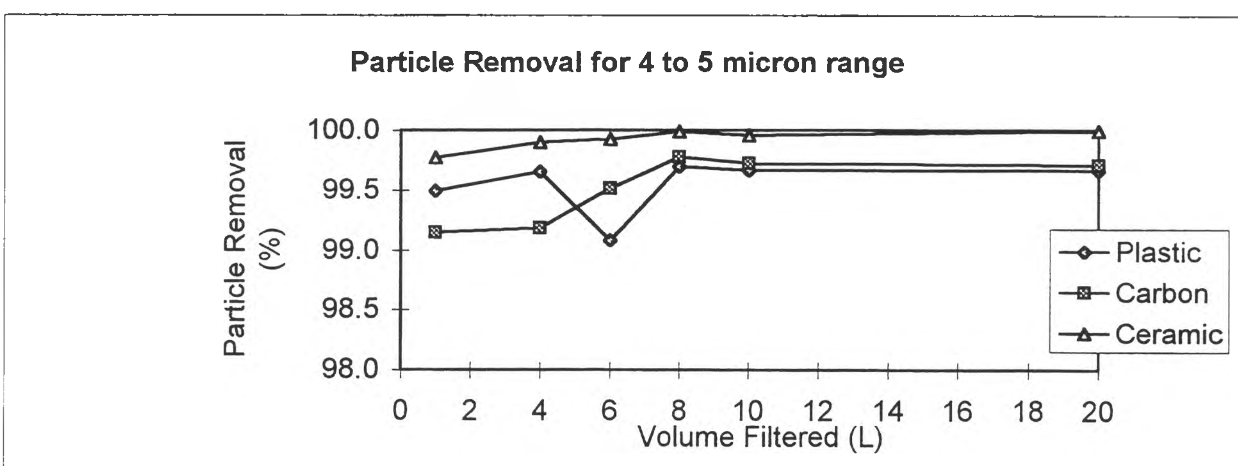

Figure D-12. Percent Particle Reduction vs. Volume Filtered for 4 to 5 micron range

PARTICLE ANALYSIS

Table D-13. Average Particle Count per mL (5 to 10 micron range)

Sample	Volume Filtered (L)							
	1	4	6	8	10	17	18	20
Influent	65983	65983	59454	67981	67981	74687	74687	71194
Plastic	293	210	410	211	228	-	-	182
Carbon	356	377	181	92	139	-	-	198
Ceramic	121	48	52	6	27	8	157	4

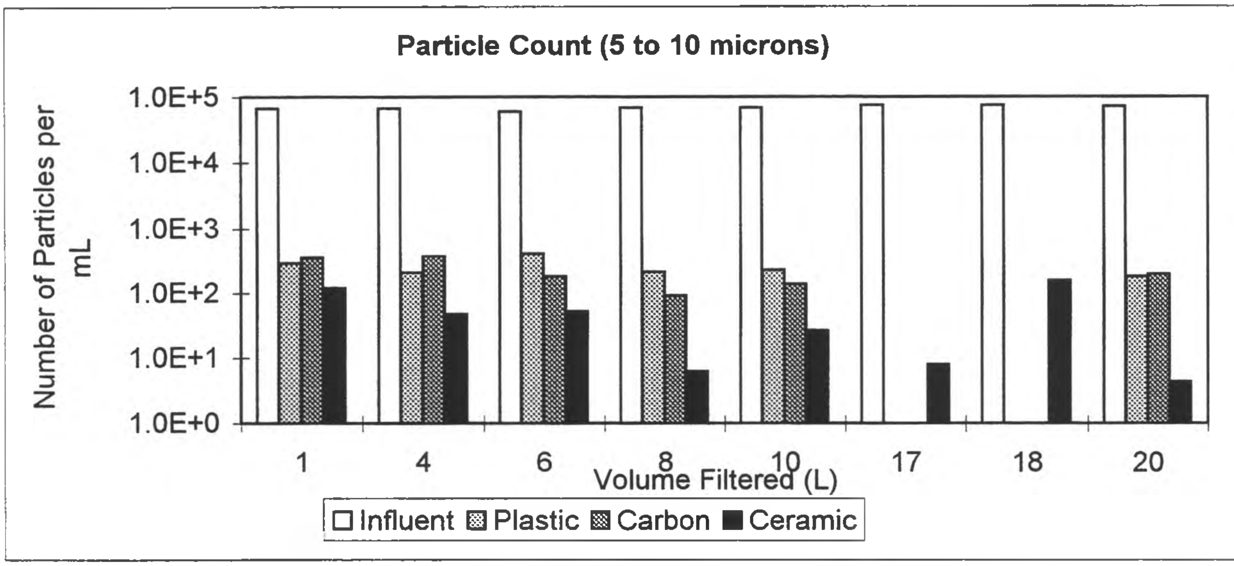

Figure D-13. Average Particle Count vs Volume Filtered (5 to 10 micron range)

Table D-14. Percent Particle Reduction for 5 to 10 micron range.

Sample	Volume Filtered (L)					
	1	4	6	8	10	20
Plastic	99.56	99.68	99.38	99.72	99.69	99.72
Carbon	99.46	99.43	99.67	99.87	99.80	99.73
Ceramic	99.82	99.93	99.91	99.99	99.96	99.99

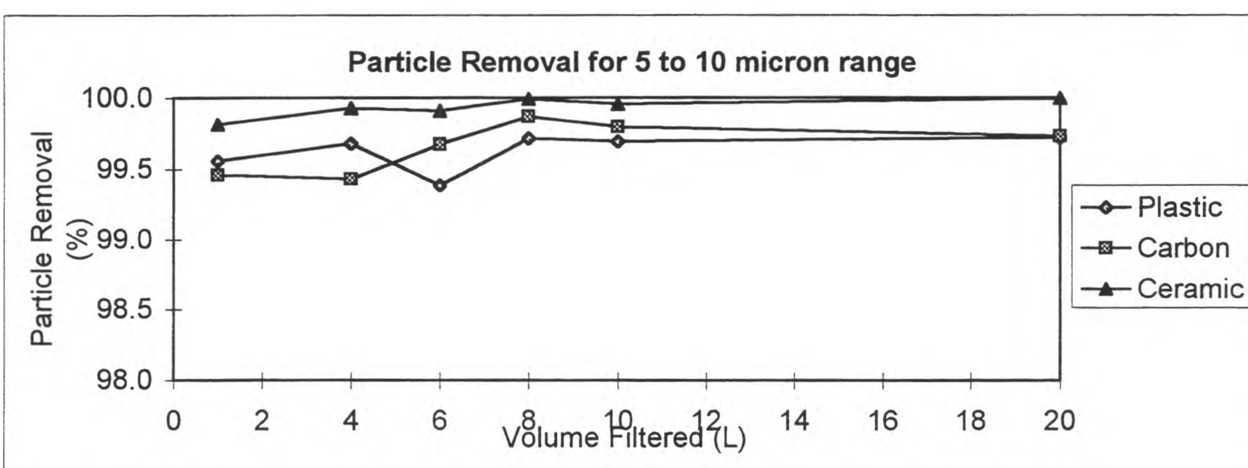

Figure D-14. Percent Particle Reduction vs. Volume Filtered for 5 to 10 micron range

PARTICLE ANALYSIS

Table D-15. Average Particle Count per mL (10 to 25 micron range)

Sample	Volume Filtered (L)							
	1	4	6	8	10	17	18	20
Influent	13810	13810	11703	12447	12447	15796	15796	14725
Plastic	58	28	47	58	105	-	-	57
Carbon	30	41	22	9	16	-	-	32
Ceramic	22	7	14	1	5	1	17	1

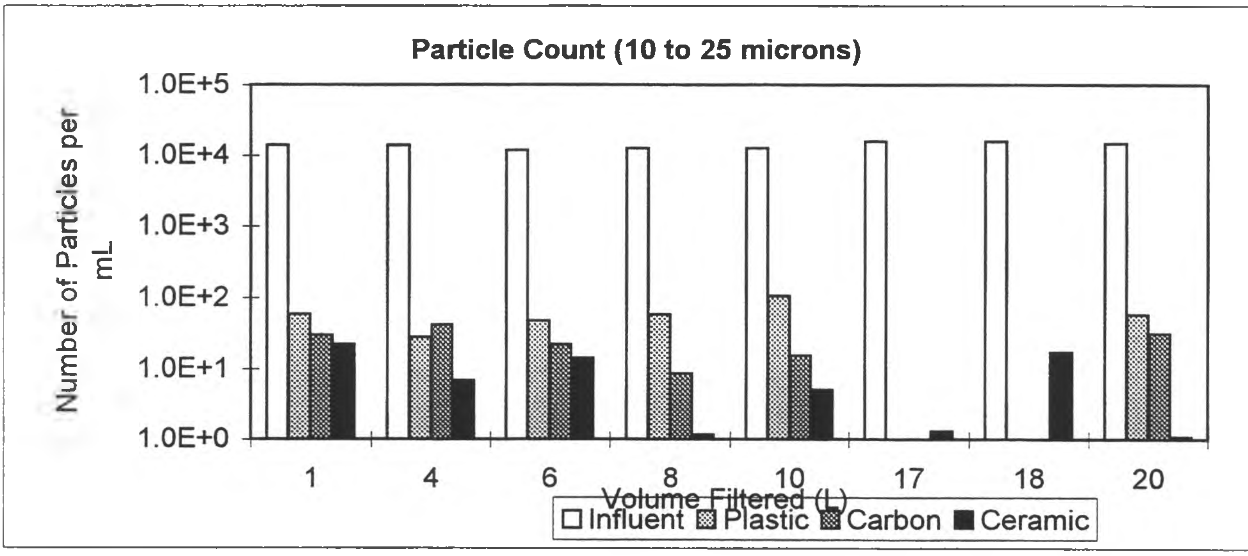

Figure D-15. Average Particle Count vs Volume Filtered (10 to 25 micron range)

Table D-16. Percent Particle Reduction for 10 to 25 micron range.

Sample	Volume Filtered (L)					
	1	4	6	8	10	20
Plastic	99.58	99.80	99.63	99.55	99.18	99.58
Carbon	99.79	99.70	99.80	99.93	99.87	99.78
Ceramic	99.84	99.95	99.87	99.99	99.96	99.99

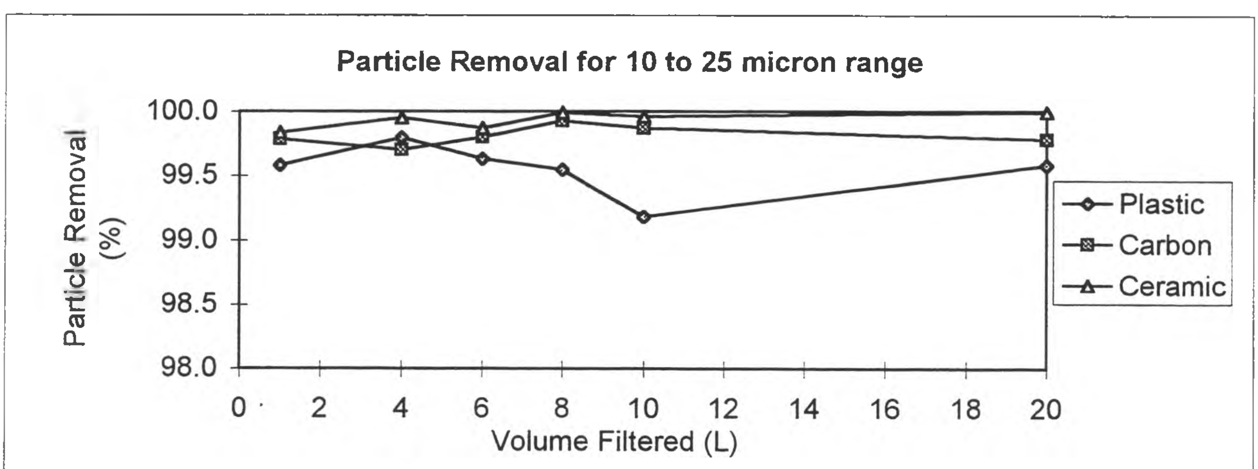

Figure D-16. Percent Particle Reduction vs. Volume Filtered for 10 to 25 micron range

PARTICLE ANALYSIS

Table D-17. Average Particle Count per mL (25 to 50 micron range)

Sample	Volume Filtered (L)							
	1	4	6	8	10	17	18	20
Influent	599.4	599.4	590.5	450.9	450.9	663.1	663.1	666.4
Plastic	1.28	0.81	2.73	1.87	2.97	-	-	1.45
Carbon	0.68	1.88	0.43	0.01	0.14	-	-	0.61
Ceramic	1.42	0.21	0.58	0.02	0.11	0.04	0.17	0.06

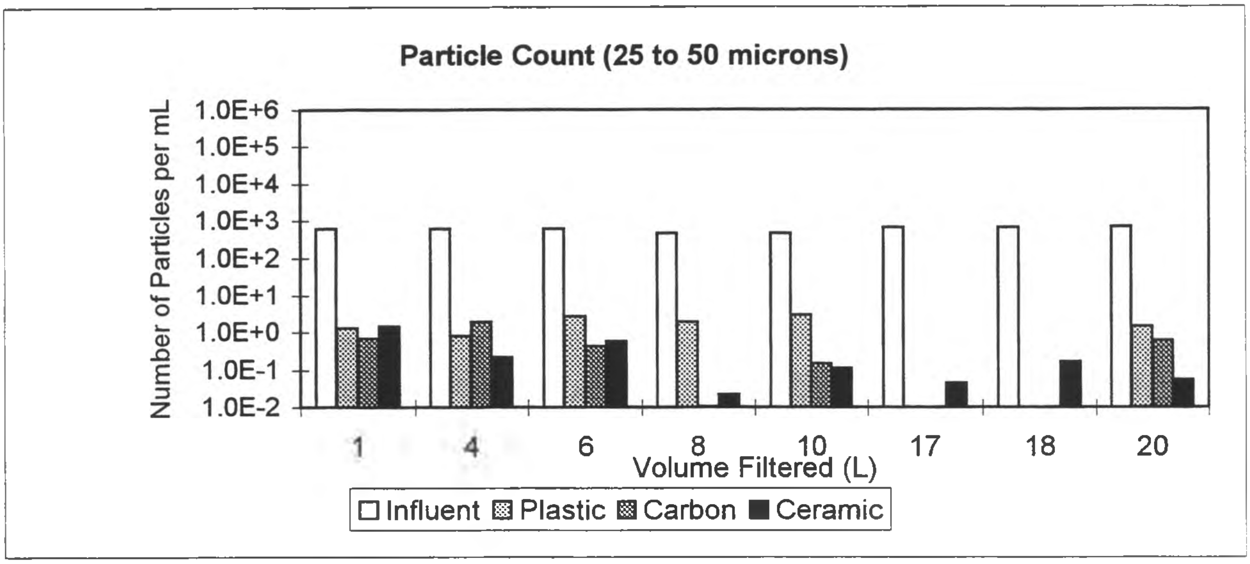

Figure D-17. Average Particle Count vs Volume Filtered (25 to 50 micron range)

Table D-18. Percent Particle Reduction for 25 to 50 micron range.

Sample	Volume Filtered (L)					
	1	4	6	8	10	20
Plastic	99.79	99.86	99.56	99.53	99.25	99.80
Carbon	99.89	99.69	99.93	100	99.96	99.90
Ceramic	99.76	99.96	99.90	100	99.98	99.99

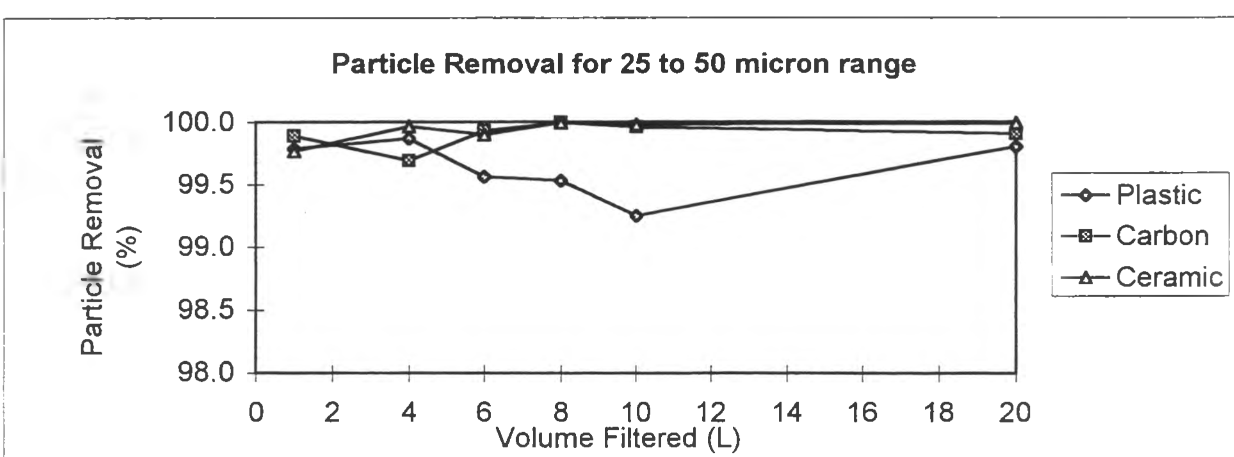

Figure D-18. Percent Particle Reduction vs. Volume Filtered for 25 to 50 micron range

APPENDIX E: TERMS OF REFERENCE

NORTHERN RIVER BASINS STUDY

TERMS OF REFERENCE

Project 4423-D1 An Assessment of Non-conventional Drinking Water in the Peace, Athabasca and Slave River Basins

I. BACKGROUND & OBJECTIVES

The quality of drinking water is based both on the quality of the source water and the treatment processes used. Under the Drinking Water Component of the Northern River Basin Study, work is currently being carried out investigating the quality of drinking water obtained from conventional water treatment facilities. However, not all people in the Northern River Basins obtain their drinking water from a water treatment plant. People living in areas where conventionally treated water is unavailable must provide some other form of treatment to obtain safe drinking water. The method of treatment may range from relatively sophisticated point-of-use treatment systems to simple methods such as boiling, melting of snow or addition of iodine pills. With greater awareness of health concerns related to chemical and microbial contaminants in drinking water, much research and study has been conducted on effect of these contaminants and methods of removing them. However, almost all of this research has focused on relatively sophisticated processes used in treatment plant facilities with little work on simple, unconventional methods. This is especially true in terms of removal efficiencies of chemical and microbial contaminants that have only recently become of concern.

The proposed project will investigate the quantity of unconventionally treated water used in the basins, the various treatment methods employed and the relative effectiveness of them. The project can be divided into three components. The first component involves the determination of the use of unconventionally treated water and methods of treatment used. Much of the information will be obtained through linkages with the Traditional Knowledge and Other Uses groups of the NRBS. To ensure that the information obtained from the project is of significance for residents in the study area, consultation with the user of unconventionally treated drinking water is an important element of this component of the study. The second component will involve a detailed literature review of pertinent material on the topic, as well as a review of existing NRBS reports on water quality parameters to determine contaminants of concern. The third component is field and laboratory testing of various treatment methods to determine their effectiveness. These tests will focus on chemical and microbial contaminants of concern in the study area.

II. PURPOSE

1. Determine the extent of use and type of unconventional treatment methods within the study area.

2. Do a complete literature review of pertinent material on this topic.

3. Field and laboratory testing of the various unconventional treatment methods to determine their effectiveness.

III. REQUIREMENTS

The work plan will be divided into three components listed below. Based on the results of these three components the final task will involve summarizing available information, assessing the quality of unconventionally treated drinking water and development of recommendations to improve drinking water quality.

1. Determination of unconventional water use and treatment methods used in the study area.

   A) Develop linkages with Traditional Knowledge and Other Uses Groups (4121-D2, Design of Questionnaires and Survey Methods).

   B) Begin a consultation process, through NRBS and using NRBS protocols, with Treaty 8 communities for their involvement in the study.

   C) Review and summarize related drinking water information from Traditional Knowledge survey and Other Uses Groups (questions on this topic are included in the surveys).

   D) Identify additional information requirements and obtain this information where possible.

2. Literature review of existing information and pertinent data.

   A) Review existing contaminant data (chemical and microbial) to determine contaminants of concern in study area (from NRBS, Federal, Provincial etc. records).

   B) Complete a detail literature review of use and performance of unconventional treat processes.

3. Field and laboratory testing of various treatment methods.

   A) Based on the results of 1. (in this section) select a number of representative locations (approximately 40) to sample and obtain firsthand knowledge of treatment processes used.

   B) Analyses of samples obtained for the compounds listed in Appendix 1.

   C) Laboratory tests of various treatment processes used to determine their effectiveness at removal of chemical and microbial contaminants.

4. Report preparation. (to be completed by March 31, 1995)

IV. DELIVERABLES

1. Draft Interpretive report - 10 copies due March 31, 1995

2. Prepare 35 mm slides for use in presentations. These would include photographs of relevant items such as examples of unconventional treatment methods etc. and a summary of the main findings of your investigation.
due March 31, 1995

IV. REPORTING REQUIREMENTS

1. The Contractor is to provide draft and final reports in the style and format outlined in the NRBS Style Manual. A copy of the Style Manual entitled "A Guide for the Preparation of Reports" will be supplied to the contractor by the NRBS.

2. Ten copies of the Draft Report along with an electronic disk copy are to be submitted to the Project Liaison Officer by March 31, 1995.

   Three weeks after the receipt of review comments on the draft report, the Contractor is to provide the Project Liaison Officer with two unbound, camera ready copies and ten cerlox bound copies of the final report along with an electronic version.

3. The final report is to include the following: an acknowledgement section that indicates any local involvement in the project, Project Summary, Table of Contents, List of Tables, List of Figures and an Appendix with the Terms of Reference for this project.

   Text for the report should be set up in the following format:

   a) Times Roman 12 point (Pro) or Times New Roman (WPWIN60) font.
   b) Margins; are 1" at top and bottom, 7/8" on left and right.
   c) Headings; in the report body are labelled with hierarchical decimal Arabic numbers.
   d) Text; is presented with full justification; that is, the text aligns on both left and right margins.
   e) Page numbers; are Arabic numerals for the body of the report, centred at the bottom of each page and bold.

      - If photographs are to be included in the report text they should be high contrast black and white.
      - All tables and figures in the report should be clearly reproducible by a black and white photocopier.
      - Along with copies of the final report, the Contractor is to supply an electronic

version of the report in Word Perfect 5.1 or Word Perfect for Windows Version 6.0 format.

- Electronic copies of tables, figures and data appendices in the report are also to be submitted to the Project Liaison Officer along with the final report. These should be submitted in a spreadsheet (Quattro Pro preferred, but also Excel or Lotus) or database (dBase IV) format. Where appropriate, data in tables, figures and appendices should be geo-referenced.

4. All figures and maps are to be delivered in both hard copy (paper) and digital formats. Acceptable formats include: DXF, uncompressed E00, VEC/VEH, Atlas and ISIF. All digital maps must be properly geo-referenced (latitude and longitude).

5. All sampling locations presented in report and electronic format should be geo-referenced. This is to include decimal latitudes and longitudes (to six decimal places) and UTM coordinates. The first field for decimal latitudes / longitudes should be latitudes (10 spaces wide). The second field should be longitude (11 spaces wide).

VI. ADMINISTRATION

The Project Liaison Officer (Component Coordinator) for this project is:

James Choles
Office of the Science Director
Northern River Basins Study
690 Standard Life Centre
10405 Jasper Avenue
Edmonton, Alberta
T5J 3N4

Home Phone: (403) 455-4812
Bus. Phone: (403) 427-1742
Fax: (403) 422-3055

APPENDIX 1

The following is a summary of the analyses to be performed on the samples taken for the evaluation of drinking water quality.

Field Analyses

pH
Turbidity
Total Chlorine
Free Chlorine
Ammonia

Conductivity
Colour
Zeta potential
Odour
Flavour

Non-field Analyses

Total Heterotropic Bacteria
Total Coliforms
Fecal Coliforms
Fecal *Streptococcus* species
Yeasts and Molds
Klebsiella species
Corrosion microorganisms (iron-reducers, iron oxidizers, sulphate reducers, sulphite reducers, thiosulphate reducers)