The Accessibility, Quality, and Safety of the Liard First Nation's Drinking Water Supply

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PROJECT TEAM

This community-based research project was the result of several organizations working together, including the University of Saskatchewan, the Liard First Nation, and Yukon College. Project team members and their roles are described below.

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KEY TERMS

Anions and Nutrients: the chemical composition of major elements, such as chloride, nitrite, and nitrate that help to identify the chemical composition of the aquifer from which drinking water is sourced.

Aquifer: An underground layer of water-bearing permeable rock or gravel/sand/silt from which groundwater is sourced.

Aquitard: A bed of low permeability along an aquifer.

Bedrock Topography: Lower level of rock where water cannot penetrate.

Hydraulic Gradients: How bedrock, aquitard, and aquifer features impact water movement.

Physical Parameters: pH (acidity), dissolved minerals (freshness), and hardness (ions that form scale) characteristics of water.

Total Metals: Iron, manganese, lead, and uranium.

ACRONYMS

AANDC – Aboriginal Affairs and Northern Development Canada
LFN – Liard First Nation
UofS – University of Saskatchewan
YRC – Yukon Research Centre

ABBREVIATIONS

GCDWQ: Guidelines for Canadian Drinking Water Quality

EXECUTIVE SUMMARY

The provision of safe drinking water is a key driver of public health and a pressing health issue facing First Nations communities in Canada. Despite numerous government assessments, training initiatives and billions of dollars in targeted funding, accessibility of safe drinking water has been and continues to be, a perennial problem in First Nations communities nationwide. The number of water-borne infections in First Nations communities is an alarming 26 times the national average and approximately 30% of community water systems are classified as posing a high risk to water quality. A recent report on water quality on reserves across Canada showed that 30% of First Nations residents viewed their tap water supply as either somewhat or very unsafe compared to 11% of residents in other small communities. Baseline information on the risks to community water supply and the potential for contaminant exposures through drinking water are not clearly understood. Such was the case in Watson Lake, Yukon, where a project was developed in partnership with the Liard First Nation (LFN) to:

1) Test up to 60 LFN private drinking water wells not subject to regular monitoring;
2) Identify the ways in which surface and groundwater are connected;
3) Identify important values, concerns, and practices related to drinking water.

Although the Liard First Nation has a well-established, large public drinking water system with regulatory oversight, routine water sampling, and certified operators for the operation of their drinking water treatment plant and water truck delivery, this project was seen as important in terms of its contributions to the baseline of information available on the community water supply.

The first project objective was addressed by sampling water from one key surface water location and groundwater from existing LFN drinking water source wells between December 2014 and February 2015. 40 wells were sampled in the LFN subdivisions of Upper Liard, Albert Creek, and 2/2.5 Mile. In addition to chemical parameters recommended by Environmental Health Services for testing, a range of contaminants of potential concern[1] were examined in order to determine whether or not military wastes, septic fields, the cemetery, fuel tanks, the landfill, or the old Canol pipeline are causing groundwater contamination.

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[1] For e.g. volatile organic compounds, polycyclic aromatic hydrocarbons, pesticides, and phenoxy acid herbicides.

The second objective was examined through defining the fundamental hydrogeological building blocks of aquifers, aquitards, bedrock topography and hydraulic gradients for the watershed, and to relate these to the groundwater and surface water regime. This information was gathered from the Groundwater Information Network where data are publicly available (data for the Upper Liard village was interpreted from 5 well logs, as the Groundwater Information Network had no data available for Upper Liard) and modeled using Leapfrog Hydro (ARANZ Geo Ltd) software.

The third objective was researched through household surveys – a total of 20 surveys were completed in Upper Liard, 2/2.5 Mile, Albert Creek, and Windid Lake. The following topics were covered in surveys: preferences, opinions, and practices relating to drinking tap water; flooding in homes and in the community; water used for drinking when at home; consumption of bottled water and other beverages; experiences with water and its impacts on the family; decision-making and communication around water in the community; water sources and how they may or may not affect daily living; and lastly, water values and concerns.

A community-based, participatory methodological framework was used to carry out this project. Foundational to this framework was the local research review committee appointed to work with our research team to refine project objectives, plan methodology, and participant recruitment. The committee was selected from a group of elders that attended an initial project meeting held in late August 2014. The group decided that representatives should come from different areas of the community and include all three villages, 2/2.5 Mile, Upper Liard and Albert Creek.

Enhancing the capacity of the Liard First Nation to manage and monitor water resources was another key component of our approach; to do so, one individual previously employed by the First Nation to conduct water quality sampling was hired to build upon those skills and two others were hired and trained.

The quality of well water tested was generally good, although there were many wells with concentrations of manganese and iron that exceeded the GCDWQ for aesthetic objectives (i.e. colour and taste), which do not pertain to toxicity and related health impacts. Although they do not present a risk to human health, the taste of water resulting from high concentrations of iron and/or manganese may be unpleasant and these metals can stain laundry, bathroom and kitchen ceramics. Chloride and nitrate concentrations were below the maximum allowable concentrations according to the GCDWQ, but concentrations varied according to distance from the highway, which suggests that road salting could be influencing these anion concentrations.

Drinking water quality deficiencies were observed in some wells in Upper Liard, Albert Creek, and 2/2.5 Mile. At one well in 2/2.5 Mile, total coliforms were reported after a second confirmation sample was taken; the Liard First Nation has since serviced the well. In addition, 4 well sites in Upper Liard and Albert Creek indicated the presence of tributyltin, albeit in concentrations below European Union and World Health Organization accepted levels for human exposure (Canadian Government guidelines on acceptable levels of exposure for tributlytin are not available). Likely sources of tributyltin include PVC piping and leachate from landfills where materials containing tributyl may be disposed of. In order to truly assess human health risk and chronic exposure, it will be important for the LFN to analyze whether these results change over time and to examine the PVC pipes used in local homes to see whether tribuytl compounds are present. None of the compounds related to potential contamination from the landfill (unless tributyltin is leaching from the landfill site), cemetery, military wastes, oil pipes, fuel tanks, or septic were detected in sampled wells.

Results of the connectivity assessment indicate that there are two major aquifers in Albert Creek, Upper Liard, and the 2/2.5 Mile area: an upper and a lower aquifer, both of which are comprised of sands and gravels. These aquifers are separated by a low permeability layer (aquitard) in most of the study area, but they may be connected locally in the 2/2.5 Mile area, because the aquitard may not be present over the whole area there. This means that the groundwater used as a source of potable water from wells in Albert Creek and Upper Liard are likely protected from contamination potentially associated with historical or present surface activities; this may not be the case for wells in the 2/2.5 mile area.

In terms of groundwater flow, the models developed in this study show that surface water bodies in the area constitute discharge zones for groundwater. For example, water levels in wells near the Liard River are higher than the elevation of the Liard River, indicating that groundwater discharges to the Liard River. Similarities in the groundwater and Liard River water chemistry confirmed this connection. Due to a lack of available information, the flow direction from the Liard dump cannot be assessed at this time, but, according to the 2004 EBA Engineering Consultant study on groundwater, groundwater flows from the dump towards the Albert Creek subdivision.

Results of the household survey show that the majority of the 20 people interviewed were dissatisfied with tap water quality; both beliefs and behaviours demonstrated this dissatisfaction in numerous ways. Most strikingly, nearly half of respondents reported rarely or never drinking their tap water. Dissatisfaction with drinking water quality strongly relates to source water contamination concerns, shared by more than half of respondents, with garbage dumping as the primary concern. Some respondents expressed concerns with potential contamination of surface water bodies in the Watson Lake area as well, the result of which, for some, is negative impacts on access to traditional medicines, traditional foods, cultural/spiritual ceremonies, and the physical health of the community.

In terms of how water quality is perceived to influence health, a range of potential concerns were highlighted by participants, from the possible presence of bacteria in household water storage tanks, the potential for contamination from spring run-off, impacts from the presence of chlorine and iron in water, and the exacerbation of a number of chronic illnesses. With the exception of the possible presence of bacteria in household water storage tanks and the potential for contamination from spring runoff, there is no evidence to support physical health impacts from the tap water tested in this study (although further testing should be done on tributyltin in the households where it was found).

Results from this study indicate that the drinking water tested— for a specific suite of general water quality parameters and contaminants—is safe to drink, and by and large protected from possible contamination from surface activities in the area, because of the low-permeability aquitard present throughout most of the study area (with the exception of the 2/2.5 Mile area). We also know that surface waters constitute discharge zones for groundwater in the area, so the likelihood of Watson or Wye Lake water, for example, contaminating well water in the area is low. Follow-up testing is advised, however, so that 1) the source/concentration of tributyltin can be confirmed in the 4 wells where it was found, and 2) the exact location of the landfill leachate can be determined so that if it ever comes into close proximity to groundwater drinking sources, the appropriate prevention and/or mitigation work can be carried out.

As the household survey portion of this project has highlighted, more work needs to be done to enhance household trust and use of tap water for drinking purposes (it is recognized, however, that the number of interviewed households in this study was small); still, tap water remains one of the most preferred drinking water sources. To increase the use of tap water as a drinking water source, survey respondents suggested that LFN give households more information on tap water safety, improve tap water clarity, reduce or eliminate chlorine and chemicals in tap water, improve tap water taste, and provide free filters for taps. Respondents also indicated a number of ways in which they would prefer to stay informed about the treatment and testing of their tap water.

It is hoped that these baseline data on water quality and the need for improved communication about drinking water safety will be used to provide essential information to guide community leaders to develop tools and methods of communicating water-related health risks, make informed decisions for cost effective and efficient water supply management, and guide policy decisions at the provincial, territorial, and federal levels.

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1.0 INTRODUCTION

1.1 BACKGROUND TO THE STUDY

The provision of safe drinking water is a key driver of public health and is one of the most pressing health issues facing First Nations Communities in Canada [1-9]. Despite numerous government assessments, training initiatives, and billions of dollars in targeted funding, accessibility of safe drinking water has been, and continues to be, a perennial problem in First Nations Communities nation-wide[3-10,11]. The number of water-borne infections in First Nations communities is an alarming 26 times the national average, and approximately 30% of community water systems are classified to pose a high risk to water quality [10,12-14]. The percentage of high-risk systems could be even greater than reported, since government assessments only account for water systems that supply five or more homes. Private wells, non-piped water delivery and small-scale distribution systems are not assessed, and information on the number, nature and utilization of these sources of drinking water in First Nations communities in Canada is lacking. Drinking water behaviors, perceptions, and attitudes toward community water, as well as the economic, cultural, and potential health implications of water consumption choices by First Nations are not clearly understood. Baseline information on the nature, availability and utilization of community drinking water sources is strikingly absent, making a First Nations household drinking water assessment both timely and urgently needed. As an outcome of the recent Water and Health in Indigenous Communities Research Workshop held in May 2009, members of the Federation of Saskatchewan Nations (FSIN)-Health and Social Development Secretariat (HSDS), Environmental Health Officers, Water Keepers and Dr. Lalita Bharadwaj, toxicologist/associate professor with the University of Saskatchewan, developed a household survey, modified and based on a drinking water survey recently conducted in British Columbia, to assess a) the nature of household water supply and use, b) awareness and attitudes towards community drinking water supply, c) drinking water behaviors (consumption of tap water versus bottled water) and d) the communication and information needs required by community members about their water sources.

In winter 2014, Dr. Bharadwaj, and Lisa Christensen, social scientist with the Yukon Research Centre, Yukon College, discussed the potential value in developing such a survey in collaboration with a Yukon First Nation looking to enhance the quality of their drinking water supply. After learning about a number of drinking water quality concerns in Watson Lake's Liard First Nation (LFN) subdivisions—Upper Liard, Albert Creek, and 2/2.5 Mile—and a proposed project by the LFN to build water management capacity, a research partnership between the Yukon Research Centre (YRC), the LFN, and the University of Saskatchewan (UofS) formed.

1.2 PROJECT GOAL AND OBEJCTIVES

The primary goal of this partnership was to contribute to a community baseline of information on important issues related to LFN-supplied drinking water quality, access, and safety. This information is complementary to the significant efforts undertaken by the LFN to date, to establish a large public drinking water system with regulatory oversight, routine water sampling, and certified operators for drinking water treatment plant (established in 2013) and water truck delivery operations.

The three objectives developed for this project include 1) test up to 60 LFN private drinking water wells not subject to regular monitoring, 2) identify the ways in which surface and groundwater are connected, and 3) identify important values, concerns, and practices related to drinking water.

2.0 THE STUDY AREA

2.1 WATSON LAKE

2.1.1 Geography

The Town of Watson Lake is located in the Liard River Ecoregion. This region is within the Mackenzie River drainage and is characterized by white spruce-dominated subarctic boreal forest. The elevation of the central part of this region, where Watson Lake lies, is rarely above 900 m. The bedrock geology is complicated by numerous fault lines including the Tintina Trench and Finlayson Lake fault zone. The major river system flood plains encompass many large fen wetland areas, which serve as excellent moose habitat. Pacific Ocean influences result in moderate precipitation and an extended summer. The vegetative growth facilitated by these conditions has made Watson Lake one of the few areas of the Yukon with forestry potential. The Liard Basin is also a major flyway for migrating birds that include the Sandhill Crane, Trumpeter and Tundra Swans (all information from this paragraph is sourced from Smith et al., 2004).

2.1.2 Governance

Local governance structures are separated into the municipality of the Town of Watson Lake and the Liard First Nation. The Liard First Nation is part of the Kaska Nation, and governs the villages of Upper Liard, Albert Creek, 2 Mile, 2.5 Mile and Windid Lake. LFN's Chief and Council include a representative from Lower Post's Daylu Dena Council, and there is a close familial and political relationship between the LFN and the Daylu Dena Council. None of the Kaska First Nation bands have signed treaty agreements or Yukon First Nation land claim agreements.

2.1.3 Population and Culture

The population of Watson Lake is estimated at 1496 as of September 2014 (Yukon Bureau of Statistics, 2014). The 2011 Household Census indicates that 67% of the population has European origins, 43% have Aboriginal origins made up of First Nations and Metis, 12% claim other North American origins, 2% have Asian origins and 1% have Latin American origins (Statistics Canada, 2013).

The Kaska people in the Watson Lake area are Athabascan speaking, and the Liard First Nation is one of two Kaska Dena communities located in Yukon and are closely related to the Ross River Dena Council of Ross River (Yukon Government, 2014).

2.1.4 Historical and Current Water Concerns

Community concerns about water are varied and result from a range of activities, such as construction of the Alaska Highway, and use of the historic air force base in Watson Lake; leaching of materials used to maintain highway-building equipment, and lake-dumping of materials associated with air force base operations. Visible evidence of historical dumping is present in Wye Lake, which adds to community concerns about the quality of local area lake water (see figure 1.0).

Figure 1.0 Picture taken Oct 24, 2014 at Wye II Lake, Watson Lake by Sarah Newton

Moreover, the Liard First Nation's Capital Director (personal communication, April 22, 2015) has indicated that there is a high degree of concern about well water quality in the Albert Creek area due to potential leachates from a nearby landfill. Three drinking water wells in this subdivision have already been decommissioned due to the presence of lead and uranium. In addition, the Liard First Nation Lands Department reports that several community members consistently purchase bottled water due to concerns that drinking water may be contaminated. In terms of aesthetics, drinking water in 2 and 2.5 mile has observable iron, which gives the water a peculiar taste, smell, and colour. There are also reports of sewage contamination during high water events.

Concerns were also raised about the local drinking water by community members during Health Canada's Climate Change and Health Adaptation Program meetings in March 2015. These concerns included the recent flooding events in Upper Liard in 2012. The Sa Dena Hes mine project is also of concern to Liard First Nation members, because of its potential impact on local area drinking water sources.

2.1.5 Drinking Water Sources and Treatment

In the Watson Lake area, there are three main ways in which drinking water is provided to local area residents; these are described in the table 1.0.

Table 1.0 Drinking water infrastructure, Watson Lake area

	***LFN water treatment plant	*LFN private water wells	Watson Lake municipal water
Year built	2013	1998	*1970s
Water source	Groundwater,	Groundwater,	*Groundwater, 2 wells in the vicinity of 1st Wye Lake and 6th Street
Water treatment system	Greensand filtration and chlorine sanitation	No treatment	**Chlorination with 12% sodium hypochlorite
Serves			*Approximately 100 people
Distribution	Water delivery by truck	Private wells and shared "cluster wells"	Gravity-fed piped water delivery
Upgrades	No upgrades	No upgrades	****1995**: New well drilled, pumping capacity upgrade. Later abandoned due to poor water quality and potential for contamination from a surrounding development. ****2006**: New well drilled but not placed into production due to high turbidity, iron, and manganese levels. ****2013**: New well drilled, supply upgrades, replacement of sewer and water mains. ****2014**: Greensand Plus Filtration, chlorination for oxidation of iron and manganese, chlorination for 4-log virus removal and secondary disinfection. ****2015 Future Planned Upgrades:** -Manganese Greensand Plus treatment method. -2 options for chlorination systems: 12% Sodium Hypochlorite or OSHG. -Primary and secondary chlorine treatments.

*Yukon Infrastructure Plan (Yukon Government, 2009)
**Conceptual Design Report (Opus DaytonKnight Consultants, 2014)
***Backgrounder: A New Water Treatment Plant for Liard First Nation (AANDC, 2013)

3.0 METHODOLOGY

3.1 COMMUNITY-BASED RESEARCH APPROACH

A participatory methodological framework was used to carry out this research. Foundational to the framework was the local research review committee appointed to work with our research team to refine project objectives, plan methodology, and participant recruitment. The committee was selected from a group of Elders that attended the initial meeting on this project in late August 2014. The group decided that representatives should come from different areas of the community and include all three villages, 2/2.5 Mile, Upper Liard and Albert Creek.

Enhancing the capacity of the Liard First Nation to manage/monitor water resources was another key component of our approach. To do so, one individual previously employed by the First Nation to conduct water quality sampling was hired to build upon those skills by: 1) completing training with Sandra Richards (GW Solutions) on well sampling methodologies[2] and 2) organizing/conducting water sampling.

3.2 WELL SAMPLING AND PARAMETERS CONSIDERED FOR TESTING

In light of identified water quality concerns in each of the Albert Creek, 2/2.5 mile, and Upper Liard subdivisions, sampling was focused on these areas. In total, 40 wells were tested and one surface water sample was obtained in order to understand surface and groundwater connectivity. The reason not all wells were sampled, was because some wells were at households that were either abandoned or burned down, no one was home, wells were capped, or a water softener treatment system was being used (this can bias water quality results), or because there was no critical concern (i.e. the well was not located close to any potential source of contamination). Permission was obtained from all households where samples were taken, and well test results were communicated back to households where requested and/or if results warranted communication/action.

The selection of parameters for testing was decided on after extensive consultation with the LFN Capital department and interviews with the Elders Council on community concerns about water. These concerns were then brought forward to our hydrogeology team at GW Solutions Inc. and parameters to address these concerns were determined. Two categories of parameters were tested for: general water quality and contaminants.

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[2] See Appendix B for training that was completed.

To test the general quality of the water, physical parameters, anions and nutrients, and total metals were looked at: concentrations were measured and compared to the Guidelines for Canadian Drinking Water Quality, developed by the Federal-Provincial-Territorial Committee on Drinking Water and published by Health Canada since 1968.

The physical parameters tested for were:

- pH, which measures the acidity and alkalinity of water;
- total dissolved solids, which is a measure of the total amount of minerals dissolved in water – this allows for the classification of water as fresh, brackish, or salty;
- hardness, which results from the presence of calcium and magnesium ions in water – these ions react with soap and tend to form a scale.

Anions and nutrients were tested in order to show the concentrations of major elements, such as chloride, nitrite and nitrate. These concentrations reveal the chemical composition of the aquifer from which drinking water is sourced.

Total metals tested for included iron, manganese, lead, and uranium.

To test for contaminants, three types of parameters were tested for:

- bacteriological (i.e. the presence of total coliforms and e coli, bacteria that may be found in drinking water);
- surface impacts (i.e. to reveal whether or not military wastes, the landfill, or the old pipeline are causing groundwater contamination; some of these parameters include volatile organic compounds, polycyclic aromatic hydrocarbon, polychlorinated biphenyl, pesticides, and phenoxy acid herbicides)
- septics (i.e. wells located near and downstream of septic tanks/fields were tested for caffeine, which indicates impact from septic contamination).

3.3 GROUNDWATER AND SURFACE WATER CONNECTIVITY

This aspect of the project was examined through defining the fundamental hydrogeological building blocks of aquifers, aquitards, bedrock topography and hydraulic gradients for the watershed, and to relate these to the groundwater and surface water regime. This information was gathered from the Groundwater Information Network where data are publicly available (data for the Upper Liard village was interpreted from 5 well logs, as the Groundwater

Information Network had no data available for Upper Liard) and modeled using Leapfrog Hydro (ARANZ Geo Ltd) software.

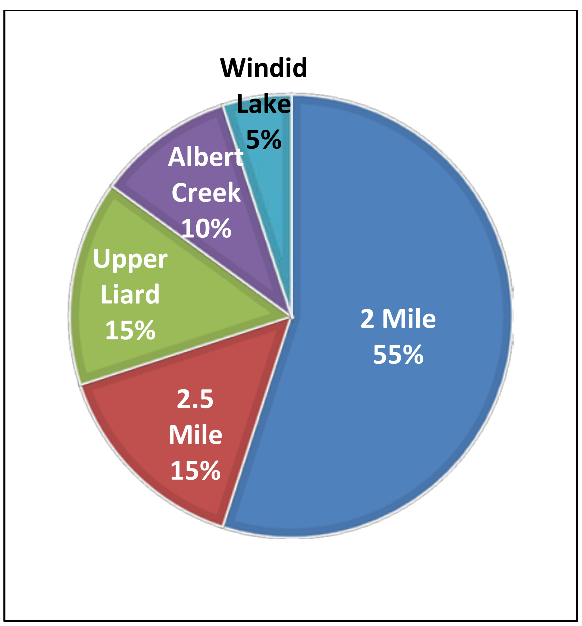
3.4 HOUSEHOLD INTERVIEWS

Household surveys were focused on the Albert Creek, 2/2.5 Mile, Upper Liard, and Windid Lake subdivisions, for LFN citizens supplied with either private drinking well water or water from the LFN drinking water treatment plant. Obtaining 60 completed household surveys was the goal, but because the survey team had limited time in the community, and community gatherings/events coincided with survey timing, participation was limited to 20 households.

Of the surveys completed, 24% of interviewees identified as male and 71% female. A typical household had 3 or fewer residents (85%) with no children as permanent residents. Five households reported having children as semi-permanent or permanent residents between the ages of 6 months to 17 years. No household reported using water to make baby formula. The majority of respondents were 55 years of age or older; 47% were between 18 and 54 years old.

Most survey participants were from the 2 mile subdivision (see figure 1.1) and 13/20 respondents reported living in their community for 41 years or more.

Figure 1.1 Percentages of Respondents Per Locale



Questions asked in the survey covered the following topics: preferences, opinions, and practices of drinking tap water; flooding in homes and the community; water used for drinking when at home; consumption of bottled water and other beverages; experiences with water and its impacts on the family; decision-making and communication around water in the community; water sources and how they may or may not affect daily living; water values and concerns; and demographics. Please refer to Appendix A for the survey instrument.

4.0 SUMMARY FINDINGS

Summary findings on water quality, ground and surface water connectivity, and household surveys are available in sections 4.1, 4.2, and 4.3 respectively. More information on each of these findings is available in Appendices C, D, and E.

4.1 WATER QUALITY

The quality of the well water was generally good in LFN wells based on data collected, although there were many wells with concentrations of manganese and iron that exceeded the Canadian Drinking Water Guidelines for aesthetic objectives (i.e. colour and taste), which do not pertain to toxicity and related health impacts. Iron and manganese naturally occur in groundwater, but because the locations of exceedances in iron and manganese are randomly spread over the three subdivisions, it is possible that these wells simply need maintenance. If not regularly maintained, accumulation of microorganisms, plants, algae, or animals on wetted surfaces can occur in aquifers near well screens. Oxidation processes supplemented by a sand filter and a MnO_2 filter can also decrease iron and manganese if desired. Further to this point, the iron and manganese concentration from the Liard River, which charges groundwater aquifers, may represent a baseline concentration of the aquifer and results for iron and manganese concentrations came in under the maximum allowable concentration from this site. This suggests that elevated levels of manganese and iron are not coming from source water, but might be occurring at individual wells needing maintenance. Although they do not present a risk to human health, the taste of water resulting from high concentrations of iron and/or manganese may be unpleasant and these metals can stain laundry, bathroom, and kitchen ceramics.

Chloride and nitrate concentrations were below the maximum allowable concentrations according to the Guidelines for Canadian Drinking Water Quality, but concentrations varied according to distance from the highway, which suggests that road salting could be influencing these anion concentrations.

Drinking water quality deficiencies were observed in some wells in Upper Liard, Albert Creek, and 2/2.5 Mile. At one well in 2/2.5 Mile, total coliforms were reported after a second confirmation sample was taken; the Liard First Nation has since serviced the well. At 4 well sites in Upper Liard and Albert Creek, concentrations of tributyltin were found, albeit below European Union and World Health Organization accepted levels for human exposure (Canadian Government guidelines on acceptable levels of exposure for tributlytin are not available). Likely sources of tributyltin include PVC piping and leachate from landfills where materials containing tributyl may be disposed of. In order to truly assess human health risk and chronic exposure, it will be important for the LFN to analyze whether these results change over time and to examine the PVC pipes used in local homes to see whether tribuytl compounds are present. None of the compounds related to potential contamination from the landfill (unless tributyltin is leaching from the landfill site), cemetery, military wastes, oil pipes, septic were detected in sampled wells. See Appendix C for further details on water quality test results.

4.2 GROUND AND SURFACE WATER CONNECTIVITY

Results of the connectivity assessment indicate that there are two major aquifers in Albert Creek, Upper Liard, and the 2/2.5 Mile area: an upper and a lower aquifer, both of which are comprised of sands and gravels. These aquifers are separated by a low permeability layer (aquitard) in most of the study area, but they may be connected locally in the 2/2.5 Mile area, because the aquitard may not be present over the whole area there. This means that the groundwater used as a source of potable water from wells in Albert Creek and Upper Liard are likely protected from contamination potentially associated with historical or present surface activities; this may not be the case for wells in the 2/2.5 mile area.

In terms of groundwater flow, the models developed in this study show that surface water bodies in the area constitute discharge zones for groundwater. For example, water levels in wells near the Liard River are higher than the elevation of the Liard River, indicating that groundwater discharges to the Liard River. Similarities in the groundwater and Liard River water chemistry confirmed this connection. Due to a lack of available information, the flow direction from the Liard dump cannot be assessed at this time, but, according to the 2004 EBA Engineering Consultant study on groundwater, groundwater flows from the dump towards the Albert Creek subdivision. See Appendix E for further details on surface and ground water connectivity.

4.3 HOUSEHOLD SURVEYS

The majority of interviewed households (i.e. 20) in this study are dissatisfied with their tap water: 55% said they were very dissatisfied or dissatisfied with their tap water, whereas only 35% were satisfied or very satisfied with their tap water (10% rated their tap water satisfaction as neutral). This dissatisfaction is evident in a number of behaviours: 9/20 households reported rarely or never drinking their tap water; purchased bottled water is the most commonly consumed drinking water; 50% of surveyed households filter their tap water for drinking, and lastly, the quality and safety of tap water is viewed as suspect by many. Still, most people would prefer to source drinking water from the tap (filtered or not) or from nearby lakes and streams.

Dissatisfaction and concerns with water not only apply to drinking water, but surface water bodies in the Watson Lake area (i.e. lakes, rivers, and streams). In the survey, the quality of surrounding-area surface water was mostly rated as good to very good (43%), 26% rated it as "okay," and 31% rated it as poor to very poor. Possible contaminants in surrounding-area surface water are believed to be from garbage dumping, mine tailings, the Alaska Highway, World War II, dumping, heavy metals, pesticides, and bacteria. Although the vast majority of those surveyed still consume traditional foods, approximately 1/3 of respondents believe water quality in the area has negatively affected at least one of the following: traditional medicines, traditional foods, cultural/spiritual ceremonies, and the physical health of the community.

In terms of how water is perceived to affect health, a range of concerns were highlighted by participants, from the possible presence of bacteria in household water storage tanks, the potential for contamination from spring run-off, impacts from the presence of chlorine and iron in water, and the cause and/or exacerbation of a number of chronic illnesses. With the exception of the possible presence of bacteria in household water storage tanks[3] and the potential for contamination from spring run-off, there is no evidence to support physical health impacts from the tap water tested in this study[4].

Despite the negative perceptions of and concerns about tap water, there is a strong desire in the LFN community to have better access to safe, good-tasting tap water; tap water is one of the most preferred sources of drinking water. In terms of ways to improve this access, many

[3] **The LFN mitigates this risk by cleaning tanks once per year.**

[4] **But further testing should be done on tributyltin presence in the four households that tested positive for concentrations. Even though the concentrations were within safe limits set out by World Health Organization and European Union, they should be monitored over time, because concentrations can change over time.**

survey respondents suggested that LFN give households information on tap water safety, improve tap water clarity, reduce or eliminate chlorine and chemicals in tap water, improve tap water taste, and provide free filters for taps. Respondents also indicated a number of ways in which they would prefer to stay informed about the treatment and testing of their tap water. See Appendix D for further details on household survey results.

5.0 DISSEMINATION OF RESULTS AND ADDITIONAL CONCERNS

All well-test results were communicated back to households where requested and/or if results warranted immediate communication/action (LFN, the steward of the wells was also notified in the case of the latter).

On June 25, 2015 a results-sharing dinner was held at the recreation centre in Watson Lake, to 1) share study results, at the community level, with community members, 2) find out if results rang true with attendees, and 3) find out if additional concerns or comments needed recognition. Interested members of the community and those who participated in well-water testing and/or household interviews were invited to attend; approximately 80 people attended. Overall, attendees were interested and engaged in the results presentation. Attendees had a number of questions about the state of their drinking water and how it should be managed, which were recorded. These questions, alongside their answers are provided in section 5.1. Section 5.2 shows additional concerns recorded at the event.

5.1 QUESTIONS ABOUT DRINKING WATER

1. *How often should water be tested?* New wells should be tested for bacteria and chemicals prior to use. Well water should be tested for the presence of bacteria at least once a year. And initially, well water should be tested for common chemical and physical parameters two years in a row. If there are no concerns and there is no significant change in water chemistry from one year to the next, then tests can be done once every five years.

2. *Should wells be disinfected? If so, how often?* It would depend on your reason for disinfection. If you rely on a well for your water, you may have to chlorinate it from time to time. Chlorination refers to the process of flushing your well and water system with a chlorine solution. This process is usually applied in order to accomplish one of the following: disinfecting to “neutralize” coliform bacteria; disinfecting after making repairs to your well or following extended periods of nonuse; temporary elimination of hydrogen sulphide (or “rotten egg”)

odours; temporary removal of iron and manganese buildup; or removal of bacteria that create slime. This information is taken from a fact sheet published by the New Brunswick Department of Health, which also outlines steps to assist in chlorinating your well and water system, http://www2.gnb.ca/content/dam/gnb/Departments/env/pdf/Water-Eau/HowToChlorinateYourWellWater.pdf

3. *How do you treat for E. Coli or Total Coliforms?* Total coliforms are bacteria that can be found everywhere in the environment. Their presence in a drinking water sample may be a result of problems in the well (e.g. cracked casing, improper seal around wellhead) or distribution system, or improper collection of the sample. Next steps include resampling to confirm results and checking for the possible source of contamination. Often disinfection of the well will address the problem. Information on disinfection is available from Environmental Health Services, Yukon Government. In some cases, remedial work on the well or installation of a water treatment system[5] may be required.

The presence of E. coli indicates recent contamination of your drinking water from human or animal feces, which, in turn, may cause serious acute (e.g. diarrhea) and long-term health problems. When E. coli is present, you are advised to boil your water prior to drinking, brushing teeth, food preparation, etc., or use an alternate supply, such as bottled water.This information is taken from http://www.hss.gov.yk.ca/pdf/well_tested.pdf.

The Liard First Nation conducts regular testing (annually) for E. Coli and Total Coliforms, on all LFN-owned wells.

4. *How can a person deal with/treat drinking water that smells like sulphur?* Sulphate reducing bacteria, which use sulphur as an energy source, are the primary producers of large quantities of hydrogen sulphide. These bacteria chemically reduce natural sulphates found in water into hydrogen sulphide. Sulphate reducing bacteria live in oxygen-deficient environments such as deep wells, plumbing systems, water softeners and water heaters. These bacteria usually flourish on the hot water side of a water distribution system. The standard treatment for sulphate reducing bacteria involves shock chlorination. There are no tests available at this time for sulphate reducing bacteria. If a shock treatment solves the problem (even for a few months),

[5] **Where appropriate, treatment options should be explored with a reputable water system supplier. Water treatment system components should be certified (e.g. CSA, NSF, UL). Costs will vary with the type of treatment technology needed. Some suppliers are listed in the yellow pages under Water Purification and Filtration Equipment.**

then bacteria is likely the cause. If the smell returns quickly, the problem may be the magnesium rod in your hot water tank or naturally occurring hydrogen sulphide in your ground water. This information is taken form a fact sheet provided by the New Brunswick Department of Health, http://www2.gnb.ca/content/dam/gnb/Departments/env/pdf/Water-Eau/RottenEggs.pdf

5. *Does water quality have a link with cancers in the community?* Results from this study, in which a specific set of parameters were tested for, indicate that the tested water is not a cause of known cancers in the community.

6. *With tap water (City of Watson Lake), there is a film that sits on top of the water, what is that?* It is possible that this film could be mineralization (calcium/magnesium) precipitating out of the water supply, but without knowing who is making this observation, and under what circumstances (for e.g. when the tap is first turned on, when the cold water tap vs. hot water tap is used), it is difficult to answer this question with certainty. It is worth noting, however, that testing on the City of Watson Lake water supply meets compliance for the health-based parameters required for routine monitoring under the Canadian Guidelines for Drinking Water Quality.

7. *Should I be concerned about chlorine in my drinking water?* Chlorine has been classified as unlikely to be carcinogenic to humans by Health Canada. Animal and human toxicological studies indicate that chlorine exhibits low toxicity, regardless of the route of exposure (ingestion, inhalation, dermal) suggesting that it has a low potential to cause human health effects at exposure levels found in drinking water. Studies in animals have not been able to identify a concentration of chlorine associated with adverse health effects, in part, because of aversion to its taste and odour. No adverse health effects have been observed in humans from consuming water with high chlorine levels (up to 50mg/L) over a short period of time (this information is from figure 2.0 on page 56 of this report).

8. *Why is my drinking water brown?* Without knowing exactly which water source this question pertains to, this question is difficult to answer. However, if the brown water originates from one of the wells tested in this study, it is likely that high concentrations of iron and/or manganese is the cause. Although they do not present a risk to human health, the taste of water resulting from high concentrations of iron and/or manganese may be unpleasant and these metals can stain laundry, bathroom, and kitchen ceramics. Strategies for reducing these concentrations may be found on page 18 of this report.

5.2 ADDITIONAL CONCERNS

At the results-sharing dinner event, one additional concern/opinion was noted, which is that many private wells in the Watson Lake area have not been installed properly. Specific observations include that well heads are located either below ground level, which contributes to contamination risk from run-off, or near the road (i.e. less than 10 feet in some cases), which, again, can pose contamination risks when run-off is an issue. In addition, small mammals such as frogs and mice (and mice feces) have been observed in well-head coverings.

Yukon Government requires that wells for large public drinking water systems be installed according to Canadian Ground Water Association Guidelines for Water Well Construction. The Yukon Rural Domestic Well Program requires that wells installed under the program meet these guidelines. These guidelines could also be used for private wells, which are not regulated in the Yukon.

In terms of inspection services available to residents on private well systems, a hydrogeologist or qualified engineer could provide this service. Some of the local water treatment technology supply companies may also have expertise in this area.

6.0 CONCLUSION

Although the Liard First Nation has a well-established, large public drinking water system with regulatory oversight, routine water sampling, and certified operators for the operation of their drinking water treatment plant and water truck delivery, this project was seen as important in terms of its contributions to the baseline of information available on the community water supply, namely:

- The water quality of up to 60 LFN private drinking water wells not subject to regular monitoring;
- The ways in which surface and ground water are connected; and
- Community values, concerns and practices related to drinking water.

Results from this study indicate that the drinking water tested— for a specific suite of general water quality parameters and contaminants—is safe to drink, and by and large protected from possible contamination from surface activities in the area, because of the low-permeability aquitard present throughout most of the study area (with the exception of the 2/2.5 Mile area). We also know that surface waters constitute discharge zones for groundwater in the area, so the likelihood of Watson or Wye Lake water, for example, contaminating well water in the area is low. Follow-up testing is advised, however, so that 1) the source/concentration of tributyltin can be confirmed in the 4 wells where it was found, and 2) the exact location of the landfill leachate can be determined so that if it ever comes into close proximity to groundwater drinking sources, the appropriate prevention and/or mitigation work can be carried out.

As the qualitative portion of this project has highlighted, more work needs to be done to enhance household trust and use of tap water for drinking purposes (it is recognized, however, that the number of interviewed households in this study was small); still, tap water remains one of the most preferred drinking water sources. To increase the use of tap water as a drinking water source, survey respondents suggested that LFN give households more information on tap water safety, improve tap water clarity, reduce or eliminate chlorine and chemicals in tap water, improve tap water taste, and provide free filters for taps. Respondents also indicated a number of ways in which they would prefer to stay informed about the treatment and testing of their tap water.

It is hoped that these baseline data on water quality and the need for improved communication about drinking water safety will be used to provide essential information to guide community leaders to develop tools and methods of communicating water-related health risks, make informed decisions for cost effective and efficient water supply management, and guide policy decisions at the provincial, territorial, and federal levels.

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APPENDIX A: HOUSEHOLD SURVEY FORM

COPY FROM INFORMED CONSENT FORM

Participant's Name:____

Mailing Address:____

Thank you for participating in this survey, your knowledge is valuable to this study. This survey focuses on several issues regarding water in your home and community: topics include the sources of water in your home, drinking water preferences, the health and safety of drinking water and the community's lakes and rivers, communication and decision-making about water, and a few questions about your household. Please remember that your participation in the survey is voluntary, and that you can choose to answer only those questions with which you are comfortable. During and after the interview you may withdraw from the study for any reason. Also, remember that your personal identity will be kept confidential at all times, but because others may see us talking with you or be able to identify your comments in reports and other products from this research, we cannot guarantee anonymity. If there is a quote from your interview that we think might be sensitive to use, we will ask for your permission to use it.

The first several questions are about your preferences, opinions, and practices of drinking the tap water from your home.

1. Where do you live? ☐ 2 mile ☐ 2.5 Mile ☐ Upper Liard ☐ Albert Creek

2. Can you tell me where your **tap water** comes from?

☐ treatment plant ____________________(name)

☐ private well

☐ other: ____

3. Do you drink the **tap water** in your home?

☐ Always ☐ Most of the time ☐ Rarely ☐ Never

4. Please rate your satisfaction with the quality of your **tap water,** on a scale of 1-5 with 1 = very dissatisfied, 2 = dissatisfied, 3 = neutral, 4 = satisfied, 5 = very satisfied.

1 2 3 4 5

⬇ ⬇

If you selected 1 or 2, please explain: ____

5. Do you filter the drinking water that comes from the **tap**?

☐ Always ☐ Most of the time ☐ Rarely ☐ Never ***(go to question #6)***

⬇ ⬇ ⬇

What type(s) of filters are used (either on the main supply pipe or tap)?

☐ Distilled water system ☐ Ultraviolet light (UV) system

☐ Reverse osmosis system

☐ Activated charcoal or carbon filter (jug filter i.e. Brita)

6. **a)** Have any of the following ever happened to you while living in your community? ***Read through the boxes and ask participant to say "yes" or "no" as you go through the possible list.***

☐ A "boil water" advisory ☐ Your well has run dry

☐ A "do not consume" advisory ☐ Strange odor from your tap water

☐ A "do not use" advisory ☐ Nothing

b) If any of these situations apply, when did the respective situation(s) happen and what was the duration of each?____

c) If boil water or do not consume advisories have ever been issued, were they appropriately timed?

☐Yes ☐No, specify: ____

7. Excluding hot beverages, do you boil your water for drinking purposes (other than during a boil-water advisory)?

☐ Always ☐ Most of the time ☐ Rarely ☐ Never ***(proceed to question #9)***

8. **a)** Do you boil your water for drinking on a daily basis?

☐ Every day ☐Almost every day ☐ Every two to three days ☐ No ***(proceed to question #9)***

b) How much water do you boil per day?

☐1-3 L (less than 1 gal) ☐4-6 L (1 – 1.5 gal) ☐ 7-10 L (2 – 2.6 gal) ☐more than 10 L (2.6 gal)

c) What method do you use to boil water?

☐ Electric stove ☐Wood stove ☐Gas/propane ☐other _______________

d) How long do you boil water for each month? ______________________(no. hours)

e) Is boiling water a problem for you?

☐ No

☐ Yes, please specify:________ ☐ Financial ($) ☐ Time ☐ other: ______________

f) Have you or anyone else in the home experienced a burn injury from boiling water for drinking purposes?

☐ No ☐ Yes

9. Do you treat your tap water in some other way besides boiling or filtering?

☐ No ***(skip to question #11)*** ☐ Yes:____

10. Why do you usually filter, boil, or treat **tap water** in some way before drinking it? ***Check all that apply. Again, explain that you can run through the list of options and they can say "yes" or "no" to the ones that apply. If there are other reasons they treat the water before drinking, they can indicate that in the "other" box.***

☐ Remove impurities ☐ Prefer filtered water ☐ Habit/got used to it

☐ Improve taste ☐ Make hot beverages with it ☐ Other ________

☐ Remove chemicals (chlorine, fluorine) ☐ Told to do it by someone

☐ Ensure safety ☐ Don't know

☐ Filtered/treated water is healthier ☐ N/A

11. Have you experienced any issues with your tap water?

☐ No ☐ Yes ***(tick the boxes that apply below)***:

☐ Discolouration ☐ Chemical contamination (oil, gas, pesticide)

☐ Sediment ☐ Chlorine levels

☐ Unpleasant smell ☐ Biological contaminants

☐ Unpleasant taste ☐ Cloudiness

☐ Lack of regulation of tap water ☐ N/A

12. Have you made a complaint related to your drinking water service in the past five years?

☐ No ☐ Yes, specify: ____

To whom did you complain: ____

13. Generally, are you satisfied with your drinking water service?

☐No ☐Yes

If you are not satisfied, what are the reasons for your dissatisfaction? ___________________

The following questions deal with flooding in members' homes and community.

14. Has your home ever flooded? ☐ No ***(skip to #17)*** ☐ Yes

If yes, how many times in the last ten years?

☐ Once ☐ Twice ☐Three to five times ☐ More than five times

15. Is your home in need of repairs as a result of flooding?

☐ No ☐ Yes ☐ Don't know

16. In the past 12 months has there been mold or mildew in your home as a result of water damage from increased moisture levels from **flooding**? ☐

No ☐ Yes

17. In the past 12 months has there been mold or mildew in your home as a result of water damage from increased moisture levels from **continuous boiling of water**? ☐

No ***(skip to #20)*** ☐ Yes

18. How long has the mold and mildew (from flooding or water boiling) been present in your home? ____ ☐ N/A

19. Does the mold exacerbate (have a negative effect on) existing medical conditions to you or anyone in your family (sensitivities to mold, respiratory diseases, asthma, allergies)?

☐ N/A ☐ No ☐ Yes: ____

20. If flooding has occurred in your community, has it impacted your or the members of your household's ability to access any of the following services? I'll read the list to you and you can tell me "yes" or "no" ***(if flooding has never occurred in the community skip to #21)***:

School or education facilities ☐ No ☐

Yes

Medical services (including medical taxi) ☐ No ☐

Yes

Local amenities (grocery store, gas station, recreational facilities, spiritual services) ☐ No ☐ Yes

Employment ☐ No ☐ Yes

Security or safety services ☐ No ☐ Yes

Emergency response ☐ No ☐ Yes

Utility services (sewer, water, propane, garbage collection) ☐ No ☐ Yes

21. For the next 3 statements, please rate your degree of concern:

(1 = not at all concerned; 2 = very little concern; 3 = neutral; 4 = somewhat concerned; 5 = very concerned)

a. Your tap water will be contaminated from flooding.

1 2 3 4 5

b. Your tap water will be contaminated from industrial activity.

1 2 3 4 5

c. Your tap water will be contaminated from mining activity.

1 2 3 4 5

d. Your tap water will be contaminated from the dumping of garbage.

1 2 3 4 5

e. The water sources (groundwater, lakes, rivers) in your community are becoming contaminated.

1 2 3 4 5

<u>The next few questions apply specifically to water used for drinking when at home.</u>

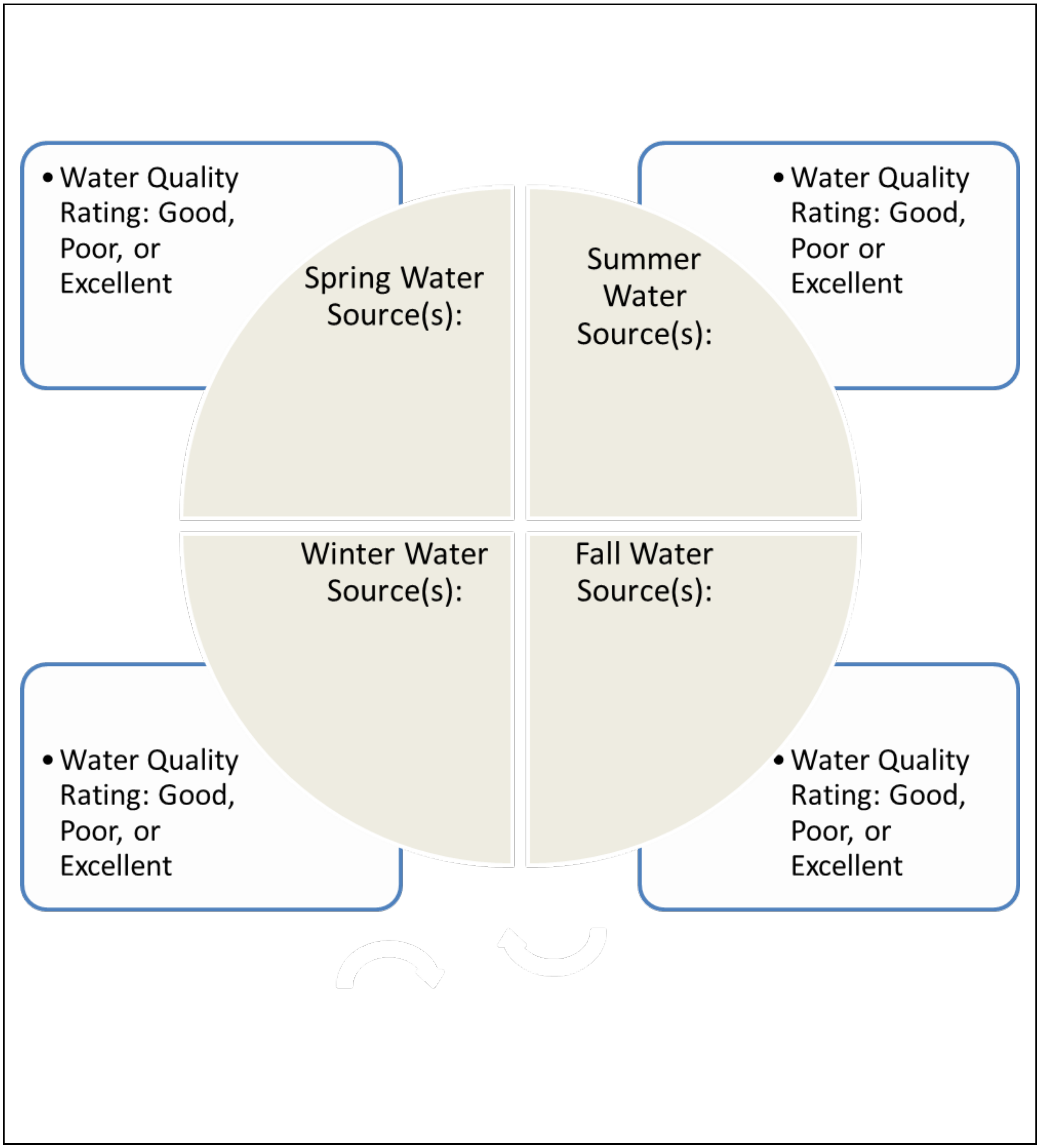
22. a) What type of drinking water do you personally consume most often when you are **at home**? ***Check all that apply.***

☐ Filtered tap water (community supplied tap water that you personally filter)
☐ Unfiltered tap water (community supplied tap water)
☐ Purchased bottled water (any size)
☐ Water from nearby lakes and streams

☐ Rainwater collected in barrels
☐ Other ____

b) Can you tell me why that is?____

23. For each season of the year, can you tell me where you source your water from and what the quality of that water is (poor, good, excellent)?



24. What type of drinking water do you **prefer** to consume?

☐ Filtered tap water (community supplied tap water that you personally filter)
☐ Unfiltered tap water (community supplied tap water)
☐ Purchased bottled water (any size)
☐ Water from nearby lakes and streams
☐ Rainwater collected in barrels
☐ Other ____

b) Can you tell me why that is?____

25. In a typical day, **approximately** what percentage of the water you drink **at home** is tap water (includes all beverages made from tap water) and what percentage is bottled water?

☐ 100% tap water, 0 % bottled water
☐ 90% tap water, 10% bottled water
☐ 75% tap water, 25% bottled water
☐ 50% tap water, 50% bottled water
☐ 25% tap water, 75% bottled water
☐ 10% tap water, 90% bottled water
☐ 0% tap water, 100% bottled water
☐ don't know

26. Of the tap water that you drink, is it mostly plain tap water or tap water used to make other drinks (i.e. coffee, juice, iced tea)?

☐ Primarily plain tap water
☐ Tap water primarily used to make other drinks
☐ Combination

27. If applicable, what are the main reasons for your choice to drink tap water (from house tap) instead of purchased bottled water when you are **at home**? ***Choose all that apply (read through the list and ask participant to indicate which ones apply).***

☐ No difference/just as good as bottled water
☐ Bottled water is too expensive
☐ We have a filter for our tap water
☐ Tap water tastes better
☐ Mix with juice/other things to disguise taste
☐ Tap water is safer
☐ Plastic water bottles are harmful to the environment
☐ Tap water is more convenient
☐ Tap water is more available
☐ Don't like drinking from plastic bottles
☐ Don't trust quality of bottled water
☐ Tap water is better for my health
☐ Don't know
☐ Other _______________________

28. If applicable, why do you **purchase** water to drink (i.e. bottled water) separate from your main supply for your household? ***Choose all that apply.***

☐ N/A

☐ Delivered water (amount supplied is not enough water for my household)

☐ Dislike taste of tap water

☐ Fear of water contamination: ☐ From main water source (ground/surface water)

☐ From water pipes

☐ From cistern

☐ From trucks

☐ Don't trust the quality/safety of tap water

☐ More convenient for drinking water

☐ Habit/got used to it

☐ Don't know

☐ Other: ____

29. What is the extent to which you agree or disagree with the following five statements about drinking water?

	Strongly agree	Agree	Disagree	Strongly disagree	Don't know
There is adequate and timely testing of your household's tap water at the water treatment plant.					
There is adequate and timely testing of your household's tap water at your household (cistern, well).					
There is adequate communication regarding the safety of your **community's** tap water.					
There is adequate communication regarding the safety of your **household's** tap water.					
After your water is tested, problems are addressed in a timely manner.					

Please answer the following questions regarding your consumption of bottled water and other beverages.

30. The size of bottled water you **buy** most often for your household is:

☐ 500ml bottle ☐ N/A

☐ 1L – 2L bottle

☐ 1 – 5 gallon jugs

☐ Over 5 gallon jugs

☐ Other: ____

31. **If you purchase water**, how much money do you spend in a **month** (on average)?

☐ Under $50 ☐ $50 - $100 ☐ $100 - $150 ☐ More than $150

☐ Do not know ☐ N/A

32. Approximately what percentage of your income is spent on purchasing bottled water?

☐ 0 – 1% ☐ 2 – 5% ☐ 6 – 10% ☐ 11 – 15% ☐ 16% or more ☐ N/A

33. Do you have concerns about drinking bottled water? ☐ Yes ☐ No ***(skip to #35)***

34. What concerns do you have about drinking bottled water? ***Choose all that apply.***

☐ no concerns ☐ contaminants in bottled water

☐ cost/ is expensive to drink bottled water ☐ contaminants from plastic part of bottle

☐ purity/ cleanliness of bottled water

☐ lack of regulation of bottled water

☐ no place to recycle plastic bottles in community

☐ hassle to recycle (lack of storage, time constraints, lack of transportation, etc.)

35. Please create an ordered list of the beverages (tap water, purchased bottled water, pop/soft drink, juice, iced tea, energy drinks, sports drinks, coffee, milk/chocolate milk, other) that you drink **in a typical day**. Please order them from most often consumed to least consumed.

1. ______________________________ Most often consumed
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________ Least consumed

36. Approximately how many cups of *straight* water do you drink in an average day?

0 cups of water ☐ 7-8 cups of water ☐

1-3 cups of water ☐ More than 8 cups of water ☐

4-6 cups of water ☐

37. **a)** Do you choose to drink beverages other than water because of the quality of your household tap water?

☐ No ☐ Yes

b) What do you choose to drink most often instead of water? _______________________________

Next I will ask you questions regarding your experiences with water and its impacts on you and your family's health. And remember you're not obligated to answer questions you're not comfortable with; just let me know if you would like to move on to the next question.

38. Do you presently suffer from a chronic illness (cancer, allergies, diabetes, respiratory disease, etc.)?

☐ No

☐ Yes (name of illness(es)____

39. Do any members of your household presently suffer from a chronic illness (cancer, allergies, diabetes, respiratory disease, etc.)?

☐No

☐Yes, who (e.g. brother, mother, grandparent) and what illness (es)?__________________________

40. Do you have any **physical health concerns** with regard to drinking the tap water that is supplied by your community?

☐ No

☐ Yes ____

41. Has anyone in your household or person visiting your home ever become ill or developed any irritations from **drinking** your household's (unfiltered) tap water? For e.g. stomach aches.

☐ No

☐ Yes Can you tell me about what happened?____

42. Has anyone in your household or person visiting your home ever become ill or developed any irritations from **bathing, cooking, cleaning, and brushing teeth** with your tap water?

☐ No

☐ Yes: can you tell me about what happened?_______________________________________

43. How would you rate the level of impact the untreated **tap water** in your household has on **your health**? I'll run through 6 different aspects of health and you can tell me if you think tap water has a positive or negative impact, or you can say you don't know.

	Negative impact	Positive impact	Don't know
Physical health			
Emotional health			
Mental health			
Spiritual health			
Hygiene			
Cooking/food			

44. Do you consider the main water supply in your home safe for drinking year round?

☐ No

☐ Yes

Can you tell me why or why not? ____

45. If someone asked you to describe healthy, safe drinking water to them, what would you say?

____

____

<u>Now I am going to ask you questions about the decision-making and communication around water in your community.</u>

46. What could your drinking water provider, LFN, do to encourage you (positively) to drink more tap water instead of bottled water? ***Choose all that apply.***

☐ Provide information on safety of tap water ☐ Make bottles water more expensive

☐ Reduce/eliminate chlorine/chemicals in tap water ☐ Improve public water fountains

☐ Improve clarity of tap water ☐ Provide (free) filters/filter tap water

☐ Provide information on problems with bottled water ☐ nothing/would not change my mind

☐ Reduce availability or ban bottled water in my community ☐ don't know

☐ Improve taste of tap water ☐ other ______________________

☐ More public water fountains ☐ N/A

What is the best way for the LFN to communicate with you about your drinking water and water sources? C***hoose all that apply.***

☐ Newspapers/ newsletters ☐ Direct mailings

☐ Television news / programs ☐ Door to door / in-home visits

☐ Radio ☐ Public meetings, workshops, debates, conferences, etc.

☐ Brochures / publications ☐ Other ________________________

☐ Internet

47. How likely would you be to use each of the following to learn more about your community's drinking water supply?

		very likely	somewhat likely	not very likely	not at all likely
Go to a website with interactive content, educational presentations and videos					
Go to social networking sites such as Facebook or Myspace					
Speak with water technician					
Speak with a government official:	LFN				
	Territorial				
	Federal				
Speak with a health professional					
Community/ town hall meeting					

48. There are a number of different sources of information about drinking water, including both tap water and bottled water. For each one, please tell me if you consider this to be a reliable or unreliable source of information.

	very reliable	reliable	unreliable	very unreliable	don't know
your local water technician					
your local Environmental Health Officer					
the Federal Government					
the Territorial Government					
LFN Government					
the LFN Health Director					

49. If there was a problem with the drinking water in _______(Upper Liard, 2 Mile, 2.5 Mile, Albert Creek) who would come forward to deal with the situation?

- ☐ People would deal with it individually
- ☐ Land users would work together as a group
- ☐ Main community leaders would deal with it separately
- ☐ All community leaders would work together
- ☐ The entire community would work together
- ☐ Other ____

The next questions address water sources in your community and how it may or may not affect daily living.

50. Please rate the water quality of the lakes, rivers, and streams located in and around your community. (1 = very poor, 2 = poor, 3 = okay, 4 = good, 5 = very good)

1 2 3 4 5

51. Do you suspect that anything is affecting the water quality in your community (e.g., pesticides, heavy metals, bacteria)?

☐ No

☐ Yes: ____

52. Do you believe that the quality of the lakes and rivers have changed over the years?

☐ No

☐ Yes, positively

☐ Yes, negatively

If yes, in what ways has it changed? ______________________________

53. Do you believe the lake and rivers in your community are safe for recreational usage (swimming, fishing, boating, etc.)? ☐ No ☐ Yes, it is safe for:

____

54. Has anyone in your household become sick or developed a bodily reaction after contact with the lakes and rivers in this area? ☐ No ☐ Yes

If yes: Would you be able to tell me about that? ______________________________

55. Has the quality of the lake and rivers in your community impacted your **desire** to participate in hunting, trapping, fishing, gathering medicines, or other activities on the land/water?

☐ No ☐ Yes: ______________________________

56. Has the quality of the lake and rivers in your community impacted your desire to consume traditional foods from hunting, trapping, fishing, and other harvesting in your community?

☐ No ☐ Yes: ______________________________

57. Do you eat traditional foods?

☐ No ☐ Yes

Can you tell me why or why not?______________________________

If yes, what? ______________________________

If yes, from where (generally, for e.g. within the Kaska TT)?______________________________

58. In your opinion, has the quality of the lake and rivers in your community negatively impacted:

a) Traditional medicines ☐ No ☐ Yes ☐ Don't know

b) Traditional foods (fish, wild game, berries) ☐ No ☐ Yes ☐ Don't know

c) Cultural/spiritual ceremonies ☐ No ☐ Yes ☐ Don't know

d) Physical health in the community ☐ No ☐ Yes ☐ Don't know

59. Do you have any comments to add about how lakes and rivers have affected traditional activities?

____

____

____

____

Second last set of questions: water values and concerns

60. Identify the 3 primary reasons you value water resources:

☐ Recreational (swimming, boating, kayaking/canoeing, walking along trails)

☐ Cultural/spiritual uses

☐ Agricultural use

☐ Industrial use

☐ Ecosystem support (support for aquatic life, wildlife, trees, plants)

☐ Aesthetics (water is pleasing to look at)

☐ Drinking water

☐ Other (please specify)____

☐ None

Last Section: Demographics

61. Gender

☐ Male ☐ Female

62. Age

☐ 18 – 24 ☐ 45 – 54

☐ 25 – 34 ☐ 55 – 64

☐ 35 – 44 ☐ 65 or older

63. Number of years residing in your community:

☐ 0 to 10 ☐ 11-20 ☐ 21- 30 ☐ 31 to 40 ☐ 41 or more

64. Number of years in your current home:

☐ 0 to 10 ☐ 11-20 ☐ 21- 30 ☐ 31 to 40 ☐ 41 or more

65. Number of people in your household: _________

66. Number of children in your household:

Ages of children	Number of children
0 to 6 mos	
6 mos to 2 years	
2 to 5 years	
6 to 12	
13 to 17	

67. Does anyone in the household make baby formula using the tap water? ☐No ☐Yes

APPENDIX B: GROUNDWATER SAMPLING TRAINING

The following points were addressed during groundwater sampling training:

- Presenting the goals of the groundwater sampling project
- Presenting location of wells/houses to be sampled (list of wells and map)
- Describing the physical and chemical parameters to be tested and their function (metals, pH, electrical conductivity, organics, etc.)
- Describing the process to take the in-situ measurements with the multi-parameter probe (calibration, readings) and to fill the corresponding field sheet. Training took place at the faucet of the training room. An explanation on how to leave the equipment at the end of the day was also included.
- Describing how to fill bottles depending on the parameter(s) to be tested
- Describing how to label bottles
- Describing how to organize samples in the cooler
- Describing how to fill the Chain of Custody form

APPENDIX C: WATER QUALITY RESULTS

2/2.5 MILE

Figure 1.2 shows the well test results for the 2/2.5 Mile subdivision. Results shown in the figure are described below.

Figure 1.2 Water quality results, 2/2.5 Mile

Beginning with physical properties and anions, wells across all subdivisions returned normal results, which are:

- The pH was measured between 7.11 and 8.29 for all samples (, indicating fairly neutral water
- Total dissolved solids ranged between 138 and 559 mg/L, which classifies the groundwater as freshwater.
- Hardness ranged from between 131 and 321 mg/L – the groundwater is classified as hard to very hard; water softening can be used to lower hardness.
- All chloride, nitrate, and sulfate values came in below the maximum allowable concentration.

In terms of the metals category, a number of wells had concentrations of iron and manganese that exceeded the Canadian Drinking Water Guidelines (the guideline refers to aesthetic objectives, colour and taste, and not to toxicity and related health impacts). Iron and manganese naturally occur in groundwater, but because the locations of exceedances in iron and manganese are randomly spread over the three subdivisions (yes, there were exceedances in the other two subdivisions we looked at) it is possible that these wells simply need maintenance. If not regularly maintained, accumulation of microorganisms, plants, algae, or animals on wetted surfaces can occur in aquifers near well screens. Oxidation processes supplemented by a sand filter and a MnO_2 filter can also decrease iron and manganese if desired. Further to this point, the iron and manganese concentration from the Liard River, which charges groundwater aquifers, may represent a baseline concentration of the aquifer, and results for iron and manganese concentrations came in “green” or under the maximum allowable concentration from this site. This suggests that elevated levels of manganese and iron aren’t coming from source water, but might be occurring at individual wells needing maintenance. Although they do not present a risk to human health, the taste of water resulting from high concentrations of iron and/or manganese may be unpleasant and these metals can stain laundry, bathroom and kitchen ceramics.

In the category of groundwater contamination by military wastes, landfill and oil pipes, none of these compounds were identified in tested samples from this subdivision.

For bacteriological contamination, there was one well in 2/2.5 mile that reported the presence of total coliforms after a 2nd sample was taken. This result has been shared with the household and the LFN has since serviced the well.

UPPER LIARD

Figure 1.3 shows the well test results for the Upper Liard subdivision. Results shown in the figure are described below.

Figure 1.3 Water quality results, Upper Liard

Results pertaining to physical properties and anions were normal across all subdivisions; these are explained on page 44.

For metals, as was the case with the 2/2.5 Mile subdivision, a number of wells in Upper Liard had concentrations of iron and manganese that exceeded the Canadian Drinking Water Guidelines. Like explained in the previous results section, it is possible that these wells simply need some maintenance.

Another metal tested for in Upper Liard was arsenic - arsenic constitutes a tracer for contamination from the cemetery as this compound is used for embalming bodies. Concentrations in arsenic were reported below the maximum allowable concentration for all samples therefore no contamination from the cemetery is suspected.

In the category of groundwater contamination by military wastes, landfill and oil pipes, none of these compounds were identified in tested samples from this subdivision.

But, at 3 well sites in Upper Liard, questionable concentrations of tributyltin were found. One of the things tributyl is used for is as a heat stabilizer in PVC pipes. Some tributyl compounds have been known to move into drinking water through PVC pipes and tributyl is also used in things like wood preservatives; it can leach into the ground, and potentially groundwater, from places like landfills, where materials containing tributyl are disposed of. Concentrations measured in the water samples were below European Union and World Health Organization accepted levels (currently, there are no such standards in Canada) and animal toxicity studies show that short term exposures to even high levels of tributyls showed no adverse side effects. In order to truly assess human health risk and chronic exposure, however, it will be important to analyze whether these results change over time (like over days or seasons), and to examine the PVC pipes used in local homes to see whether tributyl compounds are present. All of the affected households were communicated with directly about these results.

Water from 2 specific wells near (approximately 20 meters) and downstream of a septic field were sampled and tested for caffeine. Caffeine was reported to be under the detection limit (< 1 ug/L) for both samples. Therefore water from these wells do not indicate septic contamination.

No total coliforms or e coli bacteria were found in wells from Upper Liard.

ALBERT CREEK

Figure 1.4 shows the well test results for the Albert Creek subdivision. Results shown in the figure are described below.

Figure 1.4 Water quality results, Albert Creek

The results for Albert Creek are very similar to those just explained: physical properties and anion results were normal, and because sulfate, chloride, and nitrate concentrations are consistent with the other subdivisions, this indicates that leachate from the Liard landfill is not impacting the groundwater flowing through the Albert Creek subdivision.

However, something to note about anion results across subdivisions is that even though all chloride and nitrate values came in below the maximum allowable concentration, small values of concentration in chloride were detected in Upper Liard, but higher values were detected in Albert Creek. For Albert Creek, the concentrations are higher in the southeast and decrease following the groundwater flow direction. The high values may be a consequence of road salting as groundwater flows from the highway to the village. There are no high values of chloride concentration in Upper Liard, because groundwater flow direction is along the Alaska Highway. Also, relatively high concentrations of chloride were found in 2/2.5 Mile nearby the Robert Campbell Highway, which again, could indicate impact from road salting.

As was the case with the other subdivisions, there were a number of iron and manganese results that came in above the Canadian Drinking Water Quality Guidelines.

And, one well showed concentrations of tributyltin, again, at levels within the European Union and World Health Organization standards acceptable for human exposure.

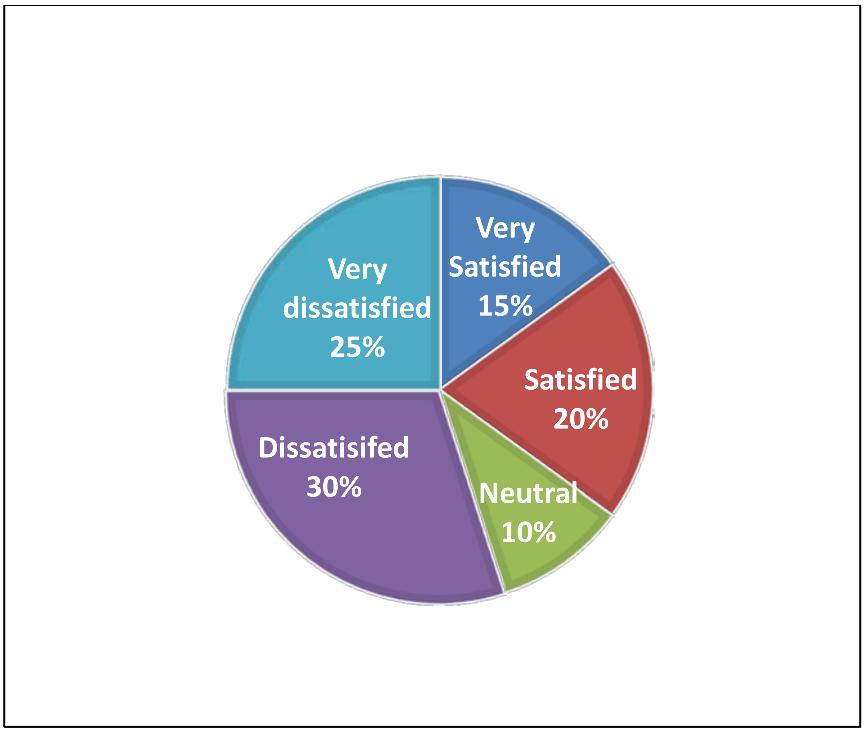
The remainder of the results, for organics and bacteria, came back normal.

APPENDIX D: HOUSEHOLD SURVEY RESULTS

1.0 HOUSEHOLD DRINKING WATER SUPPLY SYSTEM AND CONCERNS

11/20 households stated they drink tap water in their home at least most of the time, whereas 9 households reported rarely or never drinking their tap water. 10 of the 20 interviewed households access their water from private wells, 9 from the LFN treatment plant, and 1 from springs and creeks. Figure 1.5 shows satisfaction ratings with tap water.

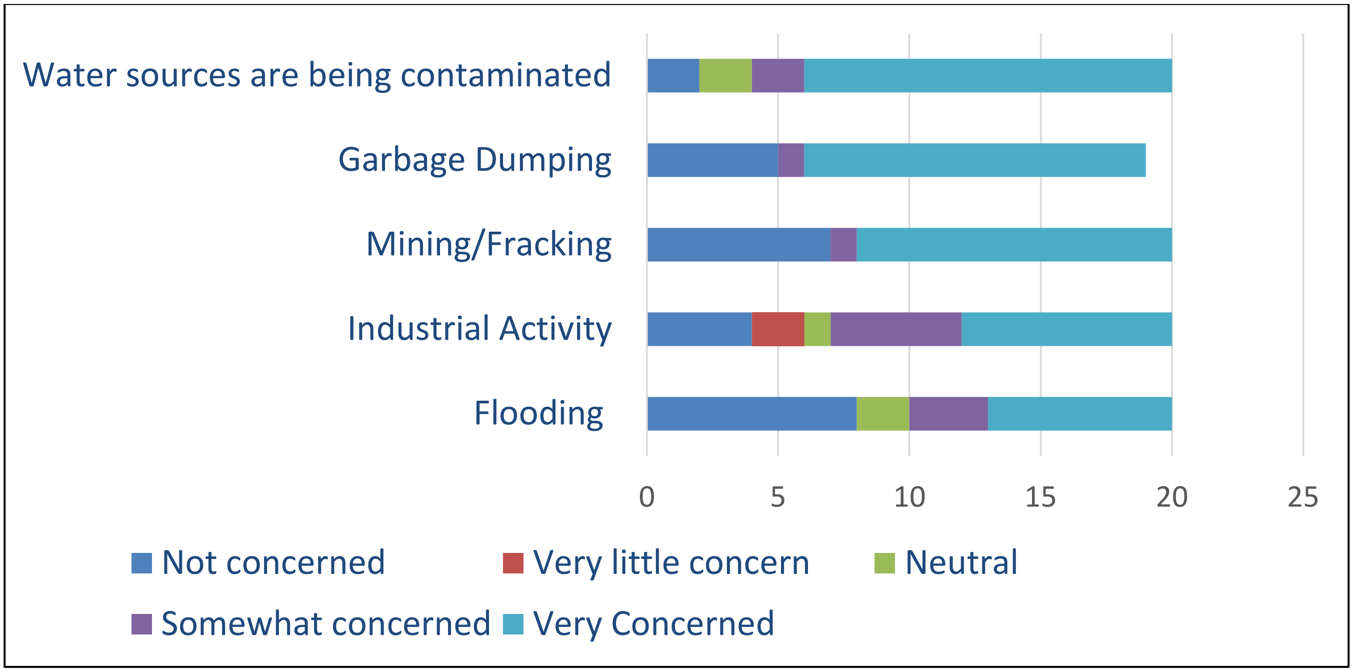
Figure 1.5 Tap water satisfaction



Chief reasons for household dissatisfaction with water included: the water tastes like bleach (unpleasant smell), there is too much iron (discolouration) or calcium in the water; sediment in the water was another common complaint. Concerns that related to public health were safety of the water delivery truck, household water storage tank, and the lack of regulation/testing around tap water.

A large proportion of surveyed households said they were concerned about source water contamination, with garbage dumping as one of the main concerns, followed by mining/fracking, industrial activity, and flooding. These concerns are illustrated in figure 1.6.

Figure 1.6 Concerns about tap water contamination in surveyed households



In terms of what people are doing to deal with these concerns, 50% of surveyed households filter their tap water for drinking[6]. But also, 9/20 households stated that they rarely or never drink their tap water. The most common reasons for filtering tap water before drinking include: filtered water is preferred, to ensure safety, and remove impurities. 20% of surveyed households boil their tap water before drinking it.

2.0 EXPERIENCE WITH WATER ADVISORIES WHILE LIVING IN THE COMMUNITY

Out of the 20 households surveyed, 7 stated that they have been under a boil water advisory in the past. These advisories lasted from 4 days to several months. 4 of the affected households believed the advisories were not timely in that they did not receive adequate warning at the

[6] **The only type of filtration currently used in surveyed households is an activated charcoal or carbon filter (i.e. a Brita). One household expressed an interest in purchasing an Ultraviolet light system.**

start of the advisory. Important to note is that boil water advisories have not been issued within the LFN community in Watson Lake for at least 5 years, since the First Nation's establishment of their own water treatment facility.

One respondent reported flooding in their home. Mold resulting from boiling water for drinking or flooding is reported to have health consequences (i.e. sinus and pneumonia infection) in 2 of the surveyed homes. Public buildings have not been affected by flooding, according to the households interviewed.

3.0 PERCEPTIONS OF DRINKING WATER QUALITY

In terms of drinking water consumed and preferred in surveyed households, purchased bottled water is the most typically consumed drinking water[7], even though water from nearby lakes or streams and unfiltered and filtered tap water are the most preferred sources of drinking water. Purchased bottled water and mountain water were preferred by the fewest number of households in the survey.

The main reason households choose to drink purchased bottled water is because they do not trust the quality and safety of their tap water[8]. Reasons households cited for drinking tap water include: its convenience, the fact that bottled water is too expensive, and the availability of tap water. Further illustrating this point is that 10/20 households said they do not consider the main water supply in their home safe for drinking year round, because they do not know if their household water tank or the LFN water delivery truck tank are cleaned regularly, or if drinking water is regularly tested, because of chlorine in the water, drying and rust effects from tap water, contamination from spring run-off, and because they do not know the source of their drinking water.

For information on beverage preferences in each surveyed household as well as costs of consuming bottled water, refer to figures 1.7 and 1.8.

---

[7] **After purchased bottled water, the following types of drinking water are preferred: filtered tap water, unfiltered tap water, spring water, water from nearby lakes and streams, rainwater collected from barrels, and mountain water (these are listed in order of preference).**

[8] **The convenience of bottled water, fear of water pipe contamination, fear of cistern contamination, dislike of tap water, fear of main water source contamination, travel, habit, other, fear of water truck contamination, and delivered water not enough were the other reasons households named for choosing bottled water.**

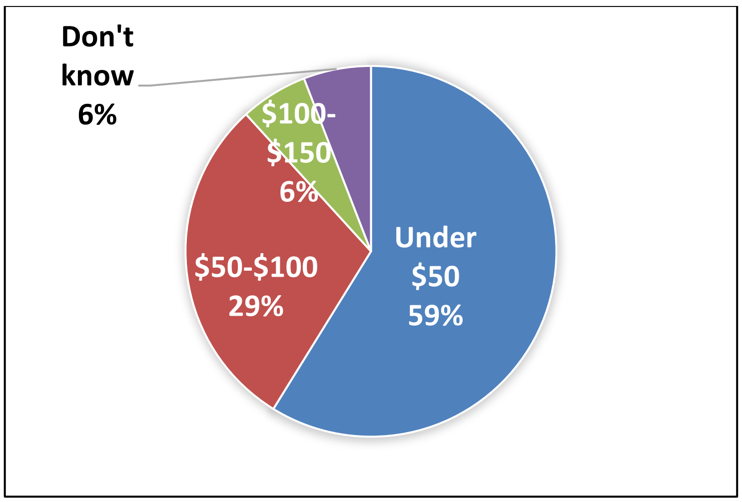
Figure 1.7 Beverage preferences

50% of surveyed households report drinking both plain tap water and tap water used to make other drinks, while 45% of households report primarily using tap water only for other drinks.

Beverages consumed in the home are most frequently coffee, tea, pop, juice, and water.

80% of surveyed households purchase bottled water.

Figure 1.8 Money spent on bottled water in one month



4.0 COMMUNICATING INFORMATION ABOUT COMMUNITY DRINKING WATER

More than 50% of survey respondents believe LFN could encourage them to drink more tap water by giving households information on its safety, improving tap water clarity, reducing or eliminating chlorine and chemicals in the tap water, improving the taste of tap water, and providing free filters for taps.

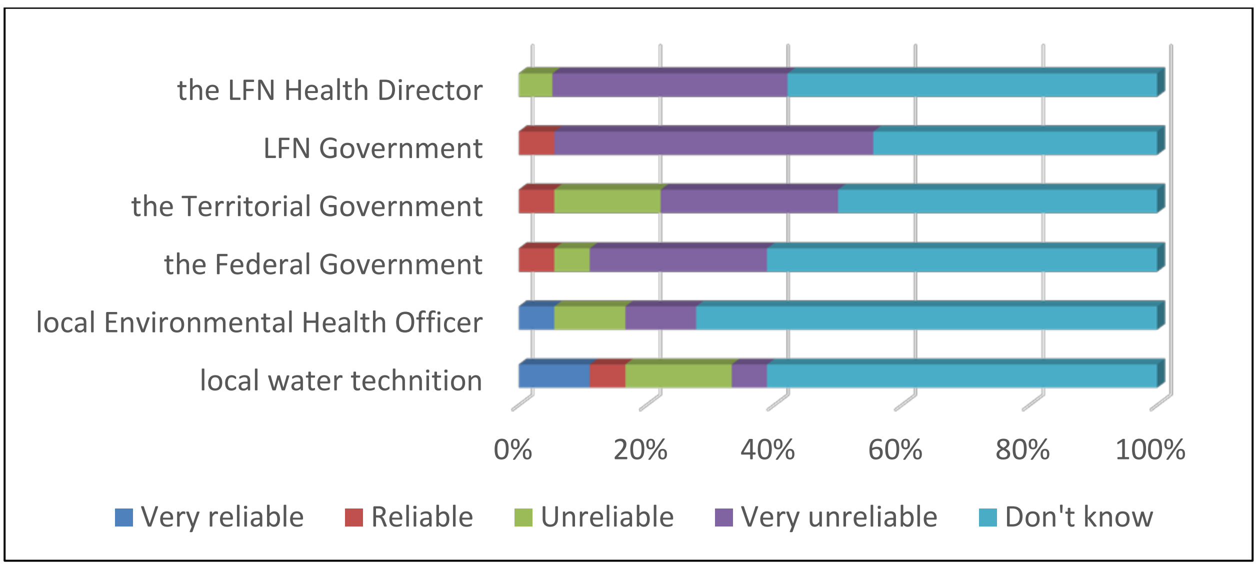
70% of survey respondents disagree or don't know that there is timely testing of treatment plant water or their personal cistern.

In terms of actions taken in response to water test results, 70% of households surveyed do not know or disagree that they are acted upon in a timely manner. Along a similar vein, 90% of survey respondents disagree or don't know that there is adequate communication about community water test results, and 85% of respondents believe the same is true about their personal water source.

When it comes to how best to inform community members about their water, survey respondents named a range of communication modes. Public meetings and direct mailings were felt to be the best ways to stay informed about drinking water, closely followed by brochures and door-to-door means. Newspapers or newsletters, radio, television news, and internet were also mentioned as suitable ways to communicate water quality.

Interesting to note is that household survey respondents are more likely to go to a website with interactive, educational content, presentations and videos; go to a social networking site, speak with a water technician or a health professional; or speak with an LFN official than speak to a territorial or government official about their community drinking water supply. Local water technicians and environmental health officers ranked the highest in terms of reliability of information by surveyed households. See figure 1.9 for more information on household water information source reliability.

Figure 1.9 Perceptions of reliability of household water information sources



5.0 WATER AFFECTING HEALTH AND PERCEPTIONS OF HEALTHY WATER

7/19 households said they have physical health concerns with their tap water. 3 of these concerns relate to chronic illness, 1 concern was about possible bacteria in the household's water storage tank and the associated impact on health, 2 other concerns were about the impact of iron and chlorine on health, and the last concern was about water quality in the springtime when run-off can be an issue.

With the exception of the possible presence of bacteria in household water storage tanks and the potential for water contamination in the springtime, there is no evidence to support physical health impacts from the tap water tested in this study. Please refer to figure 2.0 for more details on the health impacts of iron and chlorine.

Two households reported gastrointestinal illnesses (stomach ache) after drinking the tap water in their home. Gastrointestinal illness is usually associated with bacterial contamination of water. However, high levels of sulphate over the GCDWQ can result in diarrhea.

Three households reported dermatological conditions (rashes and dry skin) starting after bathing in their tap water. Skin sensitivity to additives in the water such as chlorine may cause rashes or itchy skin. Hard water is defined as highly alkaline (high pH) water that contains high levels of iron, magnesium and/or calcium ions. Seven is the ideal pH of water, and what we consider to be neutral. Each integer represents 10 times the previous one (i.e.: a pH of 6 is ten times as acidic as a pH of 7). The natural pH of the human body at a cellular level is around 7.3. Build-up or "hardening" of minerals in hard water makes it very difficult for other substances to dissolve in that water, including soaps and detergents. The various undissolved substances can leave a surface residue on your hair and skin as well as washing appliances. Thus, bathing and washing clothing in hard water can lead to increased skin irritation.

Figure 2.0 Iron and chlorine in water

Iron: Iron in well water usually does not present a health problem. Iron is needed to transport oxygen in the blood. The human body requires approximately 1 to 3 additional milligrams of iron per day (mg/day). The average intake of iron is approximately 16 mg/day, virtually all from food such as green leafy vegetables, red meat, and iron-fortified cereals.

Generally the concentration of iron in water is low, and the chemical form of the iron found in water is not readily absorbed by the body. Bacteria, may associate iron, iron bacteria, however these types of bacteria do not pose health problems.
Iron may present some concern if certain bacteria have entered a well, since some pathogenic (harmful) organisms require iron to grow, and the presence of iron particles makes elimination of these types of bacteria more difficult.

Iron in water can cause yellow, red, or brown stains on laundry, dishes, and plumbing fixtures such as sinks. In addition, iron can clog wells, pumps, sprinklers, and other devices such as dishwashers, which can lead to costly repairs. Iron gives a metallic taste to water, and can affect foods and beverages - turning tea, coffee, and potatoes black.
In general, iron in drinking water does not pose an immediate direct health threat. Iron in drinking water, however, is aesthetically unappealing and may, in turn, result in people not drinking their tap water.

Chlorine: Chlorine has been classified as unlikely to be carcinogenic to humans by Health Canada. Animal and human toxicological studies indicate that chlorine exhibits low toxicity, regardless of the route of exposure (i.e., ingestion, inhalation, dermal), suggesting that it has a low potential to cause human health effects at exposure levels found in drinking water. Studies in animals have not been able to identify a concentration of chlorine associated with adverse health effects, in part, because of aversion to its taste and odour. No adverse health effects have been observed in humans from consuming water with high chlorine levels (up to 50 mg/L) over a short period of time.

Chronic illnesses suffered by respondents and household members included: allergies, cancer, diabetes, rheumatoid arthritis, thyroid disease, bronchitis, asthma, glaucoma, and cardiac disease. There is no animal or human data that provides evidence to support an exacerbation of any of these chronic conditions by the tap water tested in this study.

Table 1.1 shows how respondents described healthy water in their own words.

Table 1.1 What is healthy water?

What is Healthy Water?
Natural spring, mountain water, or private well water
Water that is regularly tested
Water this is good quality
Water that does not need chemical additions

6.0 QUALITY OF SURFACE WATERS SURROUNDING WATSON LAKE

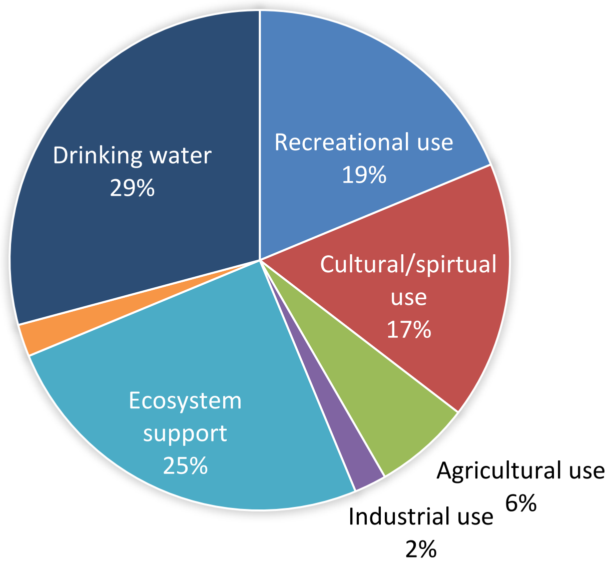
43% of surveyed households rated the quality of the lakes, rivers, and streams in and around the community as good to very good, 26% rated them as “okay,” and 31% as poor to very poor. Possible contaminants are believed to be from garbage dumping, mine tailings, the Alaska Highway, World War II, dumping, heavy metals, pesticides, and bacteria. Survey respondents also had concerns about the water in the area being used for recreation. Surveyed households believe that water quality in the surrounding area affects their ability/desire to participate in trapping, hunting, fishing, gathering medicines, and other activities on the land.

The vast majority of those surveyed (95%) still consume traditional foods, i.e. fish, moose, caribou, and other wildlife, but 35% believe water quality in the area has negatively affected at least one of the following: traditional medicines, traditional foods, cultural/spiritual ceremonies, and the physical health of the community. Themes from related comments about hunting include: feeling like household members are unable to hunt near home, feeling the need to hunt away from industrial and mining activity, and having to go much further away.

7.0 WATER AS A RESOURCE

One of the last questions asked in the survey was about why water as a resource is valued; figure 2.1 shows that drinking water was the most popular response, closely followed by ecosystem support.

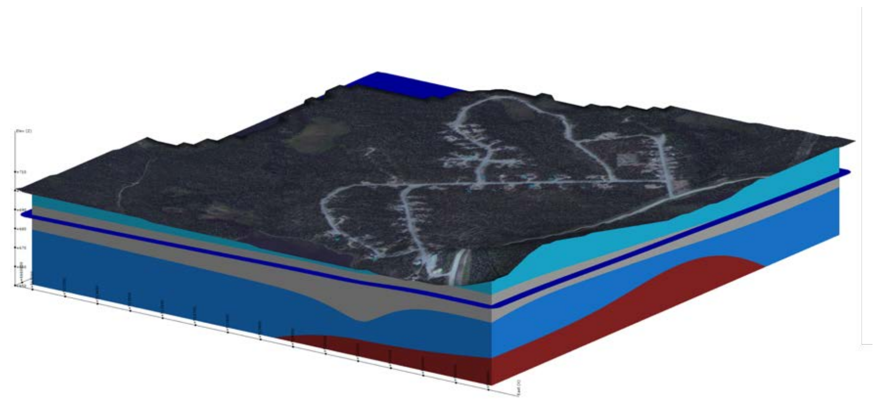
Figure 2.1 Why water as a resource is valued by surveyed households



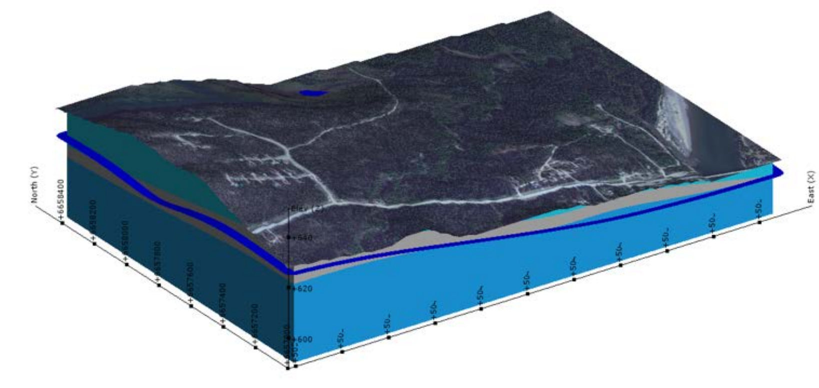
APPENDIX E: SURFACE-GROUNDWATER CONNECTIVITY RESULTS

March 31, 2015

UPPER LIARD – ALBERT CREEK AND 2/2.5 MILE HYDROGEOLOGICAL MODEL



2/2.5-Mile 3D hydrogeological model



Albert Creek and Upper Liard 3D hydrogeological model

GW Solutions Inc.

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DATA AND METHODOLOGY

GW Solutions has developed a conceptual hydrogeological model in order to better understand the surface water - groundwater regime in the Liard First Nation subdivisions of Upper Liard, Albert Creek, and 2/2.5-Mile, in Watson Lake, Yukon. The goal of the model was to define the fundamental hydrogeological building blocks of aquifers, aquitards, bedrock topography and hydraulic gradients for the watershed, and to relate these to the groundwater and surface water regime. The geological modeling application Leapfrog Hydro (ARANZ Geo Ltd.) was used to visualize boreholes in relation to surface topography, aerial imagery, well completion information, and groundwater levels.

BOREHOLE LITHOLOGY AND AQUIFERS

Borehole lithology data were accessed from the Groundwater Information Network (GIN), where data are publicly available. No lithological data were found for the Upper Liard village in the GIN, therefore the lithology was interpreted from 5 well logs provided in the 2005 EBA report. Unfortunately, the exact location for 4 of the 5 available well logs was unknown. Therefore, their locations were approximated within a one hundred meter radius.

The modeling process involves simplifying the reported soil stratigraphy by assigning a standardized lithology from borehole records. The retained classes are sand, sand and gravel, silt, clay, till, bedrock, and unknown. The "unknown" units may be subsequently re-interpreted as either being aquifers or aquitards, in the second step of interpretation. All errors in the source data, such as erroneous bedrock encounters or overlapping intervals, have also been corrected.

The next step involves grouping soil layers according to hydrogeological characteristics, either aquifers (high permeability) or aquitards (low permeability) combined with information about well completion data, groundwater elevations, surficial geology, and topography. This sorted and formatted data is then modelled in 3D.

Figure 1 and Figure 2 show the interpretation of borehole lithology as aquifer (high permeability) or aquitard (low permeability) layers.

The conceptual hydrogeological model developed for Albert Creek and Upper Liard subdivisions comprises three units:

1. An upper aquifer mainly constituted of sand and gravels to a depth of up to 25 m;
2. An aquitard (till, silts or clays) separating the upper and lower aquifer, with a thickness ranging from 1.5 to 12 m;
3. A lower aquifer, underlying the aquitard, comprising confined sand and gravels;

The hydrogeological conceptual model developed for 2/2.5-Mile comprises four units, the first three of them may be the same as Albert Creek and Upper Liard layers:

1. An upper aquifer mainly constituted of sands and gravels to a depth of up to 20 m;
2. An aquitard (till, silts and clays) separating the upper and lower aquifer, with a thickness up to 28 m; note that the aquitard may be locally absent in the area, resulting in a direct connection between the upper and the lower aquifers.
3. A lower aquifer comprising confined sand and gravels;
4. A bedrock aquifer.

It is important to note that most of the wells in Upper Liard and Albert Creek are drilled down to the lower aquifer as shown in Figure 1. Therefore water from these wells may be naturally protected from potential sources of contamination from the surface because of the impermeable barrier (aquitard) capping the lower aquifer.

As the upper and lower aquifers may be locally connected in the 2/2.5-Mile area, the lower aquifer may be more vulnerable to contamination from surface in this area.

Possible sources of groundwater contamination may include, but are not limited to, former military activities, septic tanks, dump site, cemetery site, and the former oil pipe (along the Alaska Highway). Organic contaminants resulting from these sources may be introduced in both the upper and the lower aquifers (hydrocarbons, pesticides, herbicides, Tribultyn tin, caffeine, bacteria - see the groundwater quality report). The groundwater quality report results did not reveal any contamination by organic contaminants, except the presence of Monobutyltin compounds at very low concentrations in 4 of the 7 analyzed samples and the presence of total coliforms in one sample (see the groundwater quality report for more details).

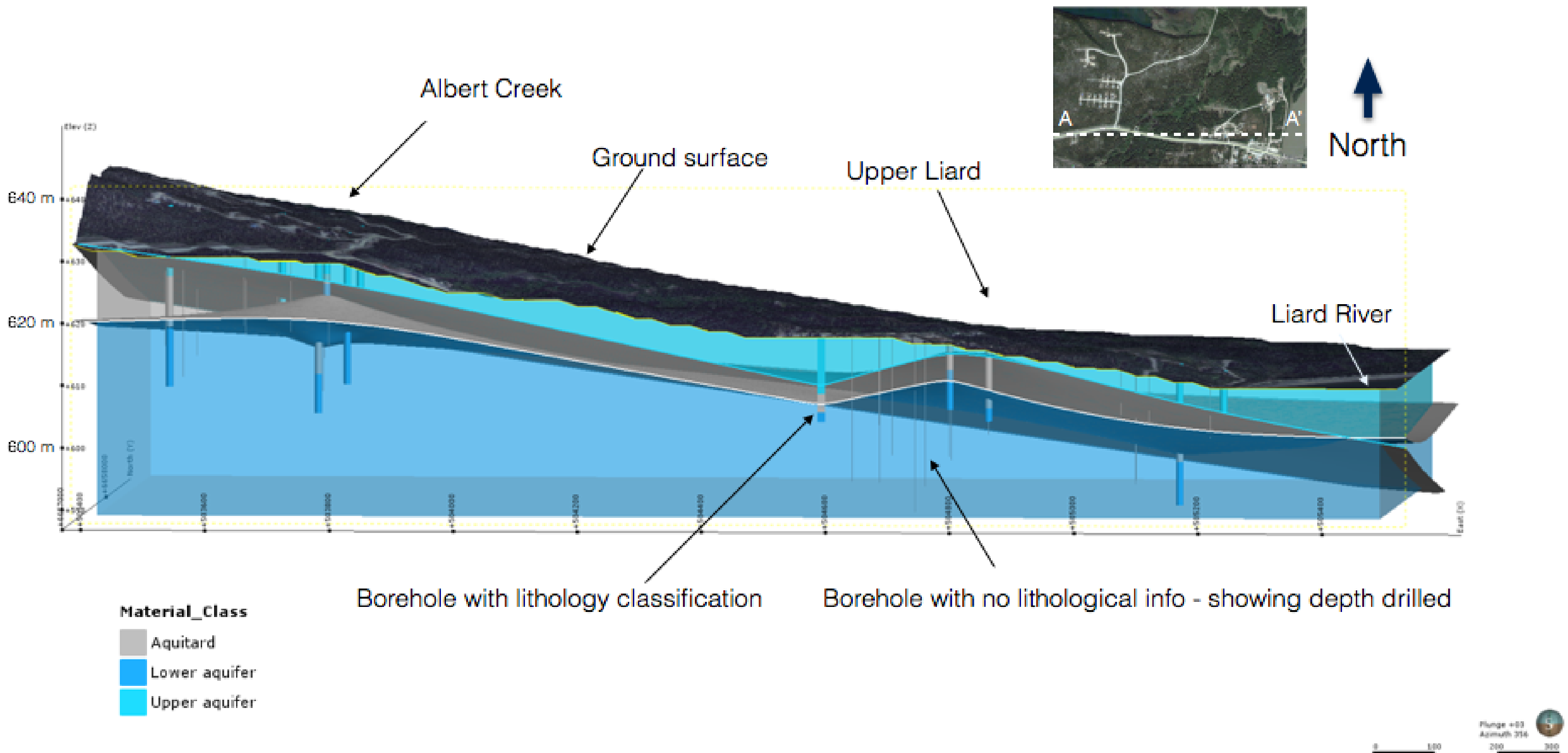

Figure 1. Hydrogeological interpretation of borehole lithologies in Albert Creek and Upper Liard. Section scene of the model taken along the Alaska Highway, looking North.

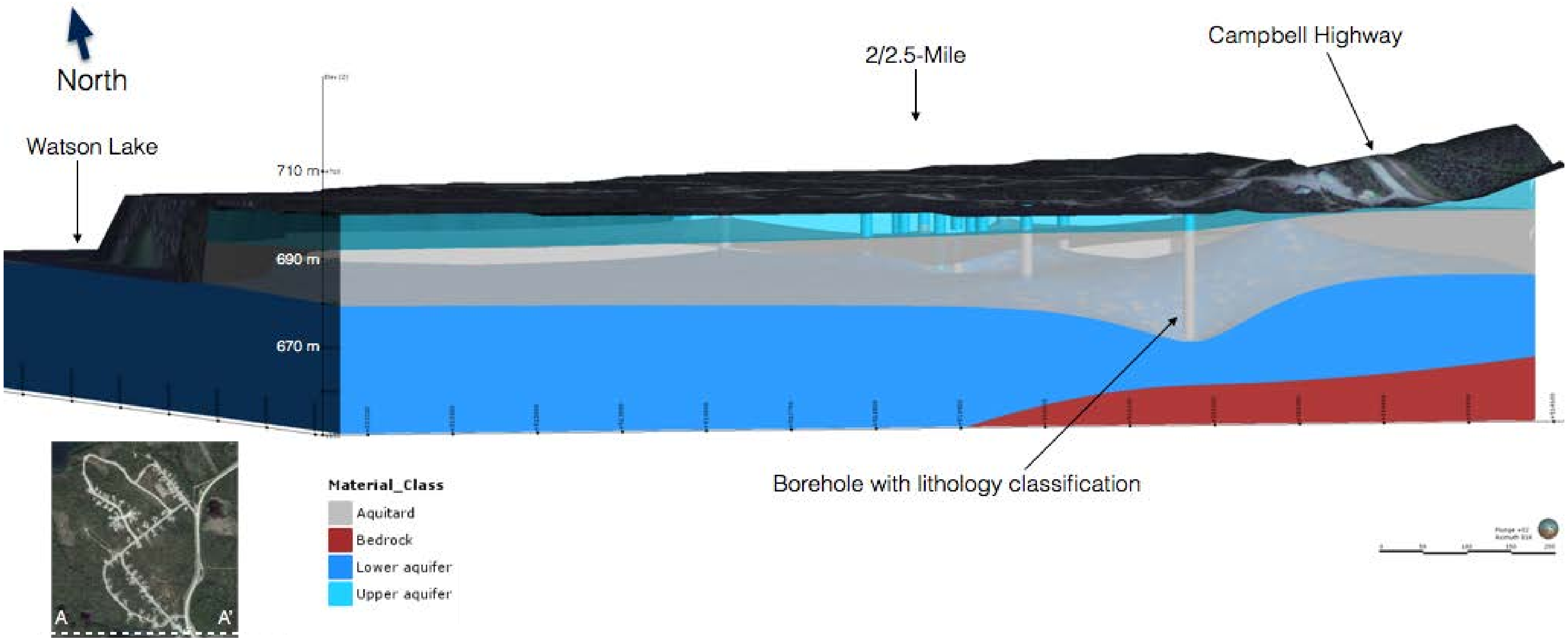

Figure 2. Hydrogeological interpretation of borehole lithologies in 2/2.5-Mile. Looking North.

BEDROCK TOPOGRAPHY

Bedrock surface was reached in only two wells in the 2/2.5-Mile area at depths of 24 and 40 m. Bedrock depth likely increases towards Watson Lake (see Figure 2).

WATER LEVELS

The water table was modeled in Leapfrog based on groundwater levels recorded during the 2004 piezometric (water table elevation) survey in Upper Liard and Albert Creek and at the time of drilling in 2/2.5-Mile.

For Albert Creek and Upper Liard, groundwater moves east toward the Liard River (Figure 3a) and north toward Half-Moon Lake (Figure 3b). The groundwater flow directions within the lower aquifer are illustrated by the orange arrows on Figure 3a and 3b. Water levels in the wells near the Liard River are higher than the elevation of the Liard River, indicating that groundwater discharges to the Liard River. Similarities in the groundwater and surface water chemistry confirmed this connection (see the groundwater quality report). Similarly water levels in the wells near Half-Moon Lake are higher than the elevation of its surface, therefore groundwater discharges to Half-Moon Lake. Hydraulic gradient in the southwestern portion of the model cannot be accurately determined because of the lack of water level data in this area (flagged with a question mark on Figure 3b). The flow direction from the Liard dump cannot be assessed for the same reason; however, according to the EBA study groundwater flows from the dump in the direction of the Albert Creek subdivision.

Hydraulic gradients for 2/2.5-Mile indicate that groundwater moves north and discharges into Watson Lake (Figure 4).

Interpreted piezometric contours (lines of equal groundwater elevation) were derived from groundwater levels recorded during the 2004 piezometric survey in Upper Liard and Albert Creek and at the time of drilling in 2/2.5-Mile. Figures 5 and 6 show an aerial view of the piezometric contours (half a meter spacing); groundwater moves from high water elevation to lower water elevation.

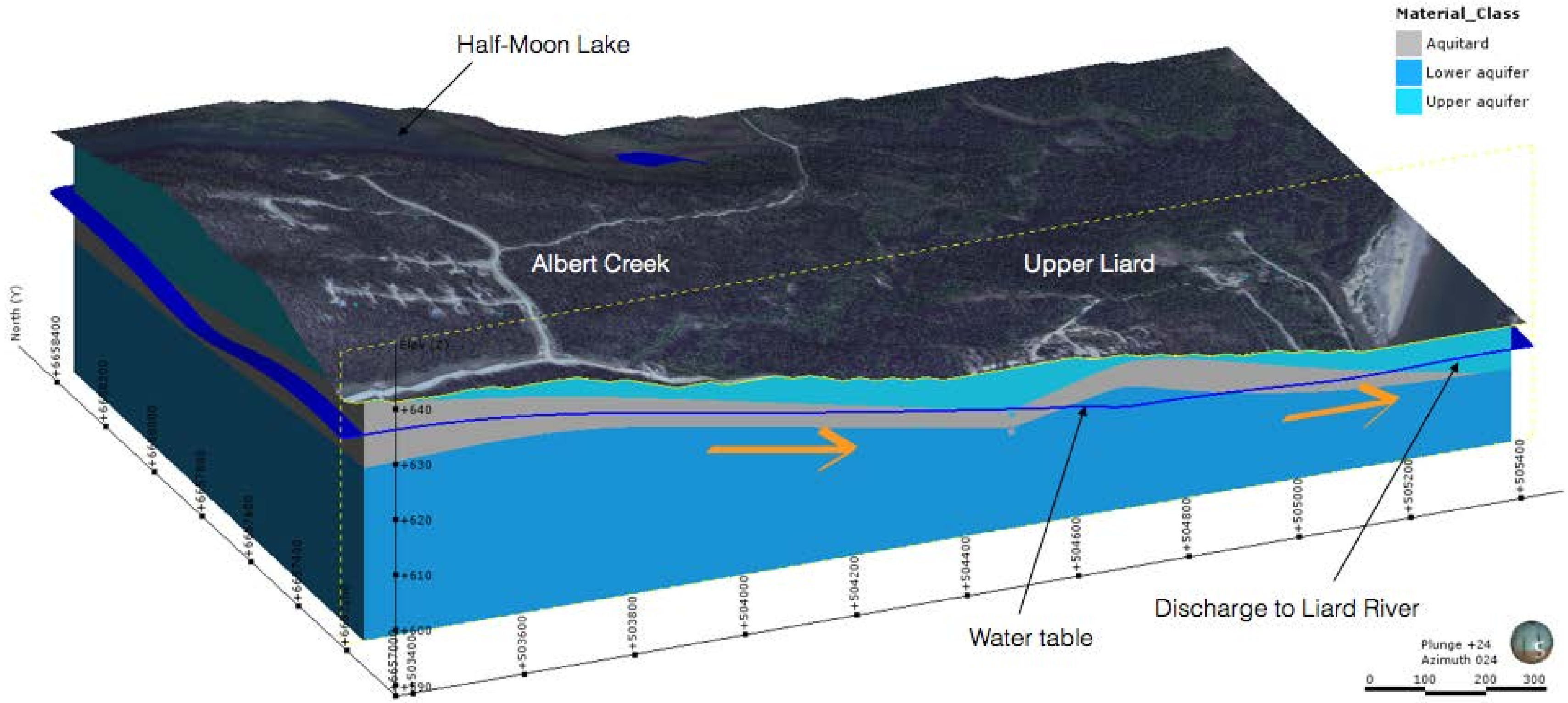

Figure 3a. Interpolated water table for Albert Creek and Upper Liard area. Section scene of the model taken along the Alaska Highway, looking North-East. The orange arrows indicate the groundwater flow direction.

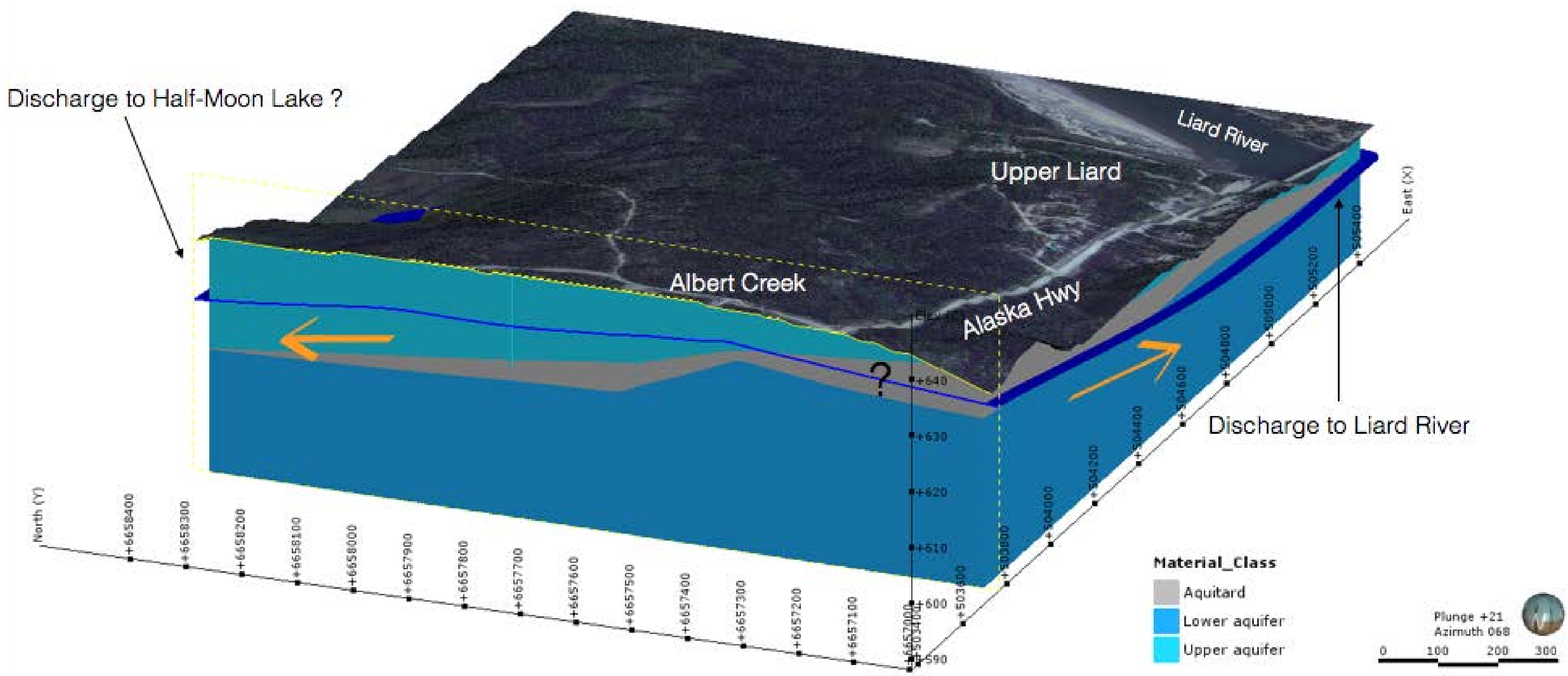

Figure 3b. Interpolated water table for Albert Creek and Upper Liard area. Section scene of the model taken along the Alaska Highway, looking North-East. The orange arrows indicate the groundwater flow directions.

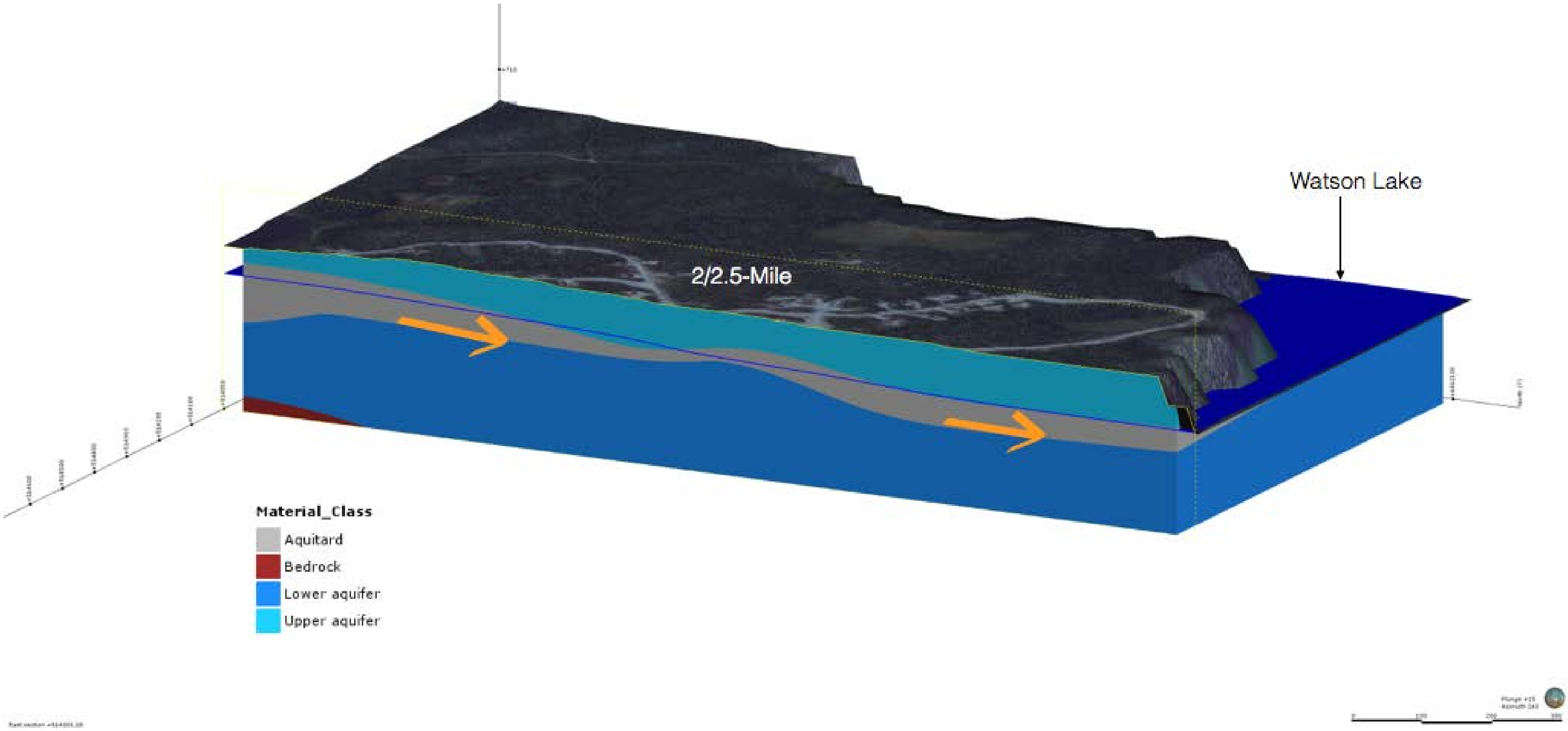

Figure 4. Interpolated water table for 2/2.5-Mile area. Section scene of the model taken along a South-North axis, looking South-West. The orange arrows indicate the groundwater flow direction.

Figure 6. Piezometric contours for 2/2.5-Mile area. The orange arrow indicates the global flow direction.

PERMAFROST

Permafrost in Watson Lake area is classified as sporadic and discontinuous based on a large scale study (Bonnaventure et al., 2012). There is no local study within the Watson Lake area that describes in more detail the presence and location of permafrost layers, therefore this cannot be mapped over our relatively small study area.

CONCLUSIONS

Based on the completed work and the data compiled and analysed, GW Solutions draws the following conclusions:

- There are two major aquifers in the Watson Lake area composed of sands and gravels: the upper aquifer and the lower aquifer. They are separated by a low permeability layer (aquitard) in most of the study area, but may be connected locally in the 2/2.5-Mile area.
- Most of the wells are located in the lower sand and gravel aquifer in Upper Liard and Albert Creek. This lower aquifer is isolated from the surface by the aquitard. Therefore, the groundwater used as a source of potable water is likely protected from contamination potentially associated with historical or present surface activities. Groundwater in the lower aquifer at 2/2.5-Mile may be more vulnerable to surface contamination because the aquitard may not be present over the whole area.
- The location of the bedrock is not well defined because very few boreholes reached the bedrock. Bedrock is found at depths greater than 20 m.
- Water elevations show that the surface water bodies constitute a discharge zone for the groundwater. Similarities in the groundwater and surface water chemistry confirmed the connection between the lower aquifer and Liard River.

RECOMMENDATIONS

The following recommendations are made to improve the hydrogeological model in the future:

- Install at least one data logger in each of the aquifers to assess the seasonal fluctuations of the water table in the aquifers.
- Conduct a piezometric survey at selected well locations to complement data logger information during periods of high recharge and high water table (late spring early summer) and low water table (mid fall). This would confirm the shape and seasonal fluctuations of the water table.
- Map the subsurface permafrost using thermal or geophysical tools.

REFERENCES

Bonnaventure, P., Lewkowicz A. G., Kremer, M., Sawada, M., 2012. A permafrost probability model for the southern Yukon and northern British-Columbia, Canada. Permafrost and Periglacial processes, 23: 52-68.

CLOSURE

Conclusions and recommendations presented herein are based on available information at the time of the study. The work has been carried out in accordance with generally accepted engineering practice. No other warranty is made, either expressed or implied. Engineering judgement has been applied in producing this letter-report.

This report was prepared by personnel with professional experience in the fields covered. Reference should be made to the General Conditions and Limitations attached in Appendix 1.

GW Solutions was pleased to produce this document. If you have any questions, please contact me.

Yours truly,

GW Solutions Inc.

Sandra Richard, Ph.D.

Hydrogeologist

Reviewed by:

Gilles Wendling, Ph.D., P.Eng.

President

Appendix 1 – GW Solutions Inc. - General Conditions and Limitations

APPENDIX 1

GW SOLUTIONS INC. GENERAL CONDITIONS AND LIMITATIONS

This report incorporates and is subject to these “General Conditions and Limitations”.

1.0 USE OF REPORT

This report pertains to a specific area, a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment. This report and the assessments and recommendations contained in it are intended for the sole use of GW SOLUTIONS’s client. GW SOLUTIONS does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than GW SOLUTIONS’s client unless otherwise authorized in writing by GW SOLUTIONS. Any unauthorized use of the report is at the sole risk of the user. This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of GW SOLUTIONS. Additional copies of the report, if required, may be obtained upon request.

2.0 LIMITATIONS OF REPORT

This report is based solely on the conditions which existed within the study area or on site at the time of GW SOLUTIONS’s investigation. The client, and any other parties using this report with the express written consent of the client and GW SOLUTIONS, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive. The client, and any other party using this report with the express written consent of the client and GW SOLUTIONS, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the area or subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made. The client acknowledges that GW SOLUTIONS is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

2.1 INFORMATION PROVIDED TO GW SOLUTIONS BY OTHERS

During the performance of the work and the preparation of this report, GW SOLUTIONS may have relied on information provided by persons other than the client. While GW SOLUTIONS endeavours to verify the accuracy of such information when instructed to do so by the client, GW SOLUTIONS accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

3.0 LIMITATION OF LIABILITY

The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of GW SOLUTIONS providing the services requested, the client agrees that GW SOLUTIONS’s liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:

(1) With respect to any claims brought against GW SOLUTIONS by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to GW SOLUTIONS under this Agreement, whether the action is based on breach of contract or tort;

(2) With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless GW SOLUTIONS from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by GW SOLUTIONS, whether the claim be brought against GW SOLUTIONS for breach of contract or tort.

4.0 JOB SITE SAFETY
GW SOLUTIONS is only responsible for the activities of its employees on the job site and is not responsible for the supervision of any other persons whatsoever. The presence of GW SOLUTIONS personnel on site shall not be construed in any way to relieve the client or any other persons on site from their responsibility for job site safety.

5.0 DISCLOSURE OF INFORMATION BY CLIENT
The client agrees to fully cooperate with GW SOLUTIONS with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for GW SOLUTIONS to properly provide the service, GW SOLUTIONS is relying upon the full disclosure and accuracy of any such information.

6.0 STANDARD OF CARE
Services performed by GW SOLUTIONS for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

7.0 EMERGENCY PROCEDURES
The client undertakes to inform GW SOLUTIONS of all hazardous conditions, or possible hazardous conditions which are known to it. The client recognizes that the activities of GW SOLUTIONS may uncover previously unknown hazardous materials or conditions and that such discovery may result in the necessity to undertake emergency procedures to protect GW SOLUTIONS employees, other persons and the environment. These procedures may involve additional costs outside of any budgets previously agreed upon. The client agrees to pay GW SOLUTIONS for any expenses incurred as a result of such discoveries and to compensate GW SOLUTIONS through payment of additional fees and expenses for time spent by GW SOLUTIONS to deal with the consequences of such discoveries.

8.0 NOTIFICATION OF AUTHORITIES
The client acknowledges that in certain instances the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by GW SOLUTIONS in its reasonably exercised discretion.

9.0 OWNERSHIP OF INSTRUMENTS OF SERVICE
The client acknowledges that all reports, plans, and data generated by GW SOLUTIONS during the performance of the work and other documents prepared by GW SOLUTIONS are considered its professional work product and shall remain the copyright property of GW SOLUTIONS.

10.0 ALTERNATE REPORT FORMAT
Where GW SOLUTIONS submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed GW SOLUTIONS's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by GW SOLUTIONS shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by GW SOLUTIONS shall be deemed to be the overall original for the Project.

The Client agrees that both electronic file and hard copy versions of GW SOLUTIONS's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except GW SOLUTIONS. The Client warrants that GW SOLUTIONS's instruments of professional service will be used only and exactly as submitted by GW SOLUTIONS. The Client recognizes and agrees that electronic files submitted by GW SOLUTIONS have been prepared and submitted using specific software and hardware systems. GW SOLUTIONS makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.