EXPLORING APPROPRIATE BUSINESS MODELS

FOR ESTABLISHMENT OF WATER QUALITY MONITORING SERVICE IN NEWFOUNDLAND AND LABRADOR

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Exploring appropriate business models for establishment of water quality monitoring service in Newfoundland and Labrador

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Executive Summary

The Government of Newfoundland and Labrador, Canada’s most eastern province, regularly tests public drinking water supplies to ensure acceptable levels of any microbiological, physical or chemical contaminants. Private water supplies, including wells, however fall outside the mandate of these testing regimes and monitoring is the sole responsibility of the individual well owner. There are over 40,000 wells in Newfoundland and Labrador servicing approximately one fifth of the total population. Limited information on private well water quality is available, especially for physical and chemical contaminants. Preliminary studies show that wells in parts of the province are contaminated with bacteria, arsenic and fluoride, but the extent of this problem is unknown. The following research seeks to address this important public health issue through three main pillars.

The first pillar is to assess and articulate the public health risk. A scan of provincial government water quality reports of public wells was performed to create a proxy model of the potential risk of private well contamination. Our results show potential problems with toxic levels of arsenic, barium, cadmium, chromium, lead, mercury and selenium. In total, this model shows 24,000 people, or about 5% of the province’s population at risk for potential exposure to toxic drinking water contaminants.

The second pillar is a population perspective provided by interviews conducted with the well owners, representatives from municipal and provincial government, laboratory professionals and medical professionals across the province. Key messages from these interviews help to inform the solutions, and address what the problem on the ground with the people who will be looking to utilize this service.

Finally, the third pillar is a high-level business model for a solution: a water quality monitoring service in Newfoundland and Labrador. This business model, including financial projections and information on a possible configuration for analytical equipment, is presented as groundwork evidence for future entrepreneurs to use to develop such a service in Newfoundland and Labrador that is a sustainable solution to an important public health risk.

Introduction

Project Background

The government of Newfoundland and Labrador is committed to providing the public with clean and safe drinking water. In order to achieve this goal a number of actions have been initiated. For example, the *multi-barrier approach* includes source protection, water treatment, water system operation and maintenance, water quality monitoring and reporting, regulatory inspection and mitigation planning, and operator education and training (DOEC, 2015). Public water supply systems treat water to ensure free from any microbiological contamination. The Department of Environment and Conservation (DOEC) also measure several non-microbial parameters of the *Guidelines for Canadian Drinking Water Quality* (GCDWQ) as the indicators of water quality. However, private water sources are outside this mandate and lack mandatory treatment and monitoring guidelines.

In Newfoundland and Labrador the drinking water quality mandate is shared between the provincial and municipal governments. Within the provincial government, four departments share responsibility for various aspects: Environment, Municipal and Provincial Affairs, Health and Community Services, and Government Services and Lands. However, the actual operation and maintenance of water supply systems and delivery of water to consumers is the responsibility of municipal governments (DOEC, 2015). The delivery of drinking water is based on three key criteria: clean, safe (free from pathogens and toxic substances) and secure (meet the present and future demands) drinking water to all citizens of this province. The main components of the approach are: source protection, water treatment, water system operation and maintenance, water quality monitoring and reporting, regulatory inspection and mitigation planning, and operator education and training.

The province uses non-microbial parameters of the GCDWQ (color, pH, turbidity, aluminum, arsenic, cadmium, chloride, chromium, copper, dissolved organic carbon (DOC), iron, lead, manganese, mercury, sodium, nitrate, sulphate, total dissolved solids (TDS), zinc and specific conductivity) as indicators of water quality. The principal goal of the multi-barrier approach is to ensure that adequate barriers are in place at each stage of the water supply system in order to minimize the possibility of pathogens and other contaminants entering into the water and, thereby, to ensure the safety of drinking water (DOEC, 2015). But these quality measures apparently do not apply to the private sources (groundwater and other sources), which are mostly located in remote rural areas. The Department of Health and Community Services (DOHCS) provides free services to analyze the domestic water for E. Coli. However, there is a low utilization of this service that might indicate lack of awareness, accessibility of the service or both.

The responsibility of monitoring the private water sources lies with well owners. This can potentially pose a threat to those people who rely on private water as a source for drinking, cooking and other domestic purposes. Approximately 30% of the population of the province uses groundwater for household purposes. Of those, approximately 75% (i.e. 23% of the total population) are dependent on private wells (Roche et al. 2013). It is estimated that total 40,000 private wells are being used in the province and most of the private well users live in small rural communities. This poses significant risk if wells are not monitored for quality and microbiological contamination.

Non-compliance with the requirements of the certificates of environmental approval and GCDWQ guidelines are also major problems. Even if well owners check water quality after sinking, some contaminants can take years to appear in the groundwater and thus initial satisfactory reports will not guarantee a safe source of drinking water for subsequent years. Furthermore, many people are also dependent on ponds, springs and brook for regular uses and these sources remain unmonitored as well. Once again, significant risks emerge for the public health of private well users.

Regular monitoring of private water sources is needed to prevent any form of adverse health outcomes. The provincial government send water samples for physical and chemical tests to an accredited private lab in Ottawa. For communities, deprived of public water supplies, it is very inconvenient using the existing analytical services due to high cost and inaccessibility.

Rationale

To begin to articulate the potential risk, it is necessary to understand what the key health risks, especially from low-level exposure to the identified chemicals are. The Health Canada Guideline values indicate levels of a contaminant that are considered to pose an acceptable health risk based on chronic consumption though individual tolerances and susceptibilities vary. Furthermore, guideline values regularly change as more evidence is presented. For example, the guideline value for the safe consumption of selenium is currently under debate (Gore, Fawell, & Bartram, 2010). Should guideline values be lowered, as arsenic was recently, even more of the population would be considered at risk. A summary of potential health risks from exposure to chemical contaminants is presented in Table 1. This information is compiled from the database of the Agency for Toxic Substances and Disease Registry of the U.S. Department of Health and Human Services (ATSDR, 2015).

Table 1. Drinking water contaminants and associated health risks

Health risk	Contaminant causing increased health risk
Bladder Cancer	arsenic
Liver Cancer	arsenic
Lung Cancer	arsenic, cadmium
Kidney Cancer	lead, cadmium
Skin Cancer	arsenic
Stomach Cancer	chromium
Cardiovascular Disease	arsenic
Hypertension	arsenic, barium, lead
Stroke	arsenic
Neurological Weakness	lead, mercury
Attention Deficit Disorder (ADD)	lead
Decreased Intelligence Quotient (IQ)	arsenic, lead
Kidney Damage	cadmium, lead
Diabetes	arsenic
Skeletal Risks	cadmium, selenium
Reproductive Risks	arsenic, lead
Selenosis	selenium

This series of health risks represents a significant burden of disease and has serious economic implications in Newfoundland and Labrador. Estimating this economic burden is difficult, but some data for 2010-2011 is available for the province by case mix group from the Canadian Institute for Health Information (CIHI). Cost estimates, according to the CIHI Patient Cost Estimator are presented in Table 2.

Table 2 Treatment Costs by Case Mix Group in 2010-2011 in Newfoundland and Labrador (CIHI, 2014)

Condition	Estimated Total Average Cost ($)	Estimated Average Cost per case ($)	Number of Cases
Bladder, renal cancer	190,269	7,047	27
Skin cancer	Data unavailable	6,505	Data unavailable
Liver, pancreas cancer	378,240	9,456	40
Bowel, stomach, intestine cancer	541,730	7,739	70
Diabetes	3,072,130	5,207	590
Stroke	3,251,997	8,813	369
TIA (mini-stroke)	791,508	3,716	213

While these numbers present a serious economic burden, there are further economic considerations that add to the problem. These numbers do not take into account the economic impact of days sick and off work, or the financial burden on families from time taken away from work for sick children for example. Furthermore, decreased intelligence quotient has a societal impact that is difficult to quantify. Though it is unknown what portion of these conditions and costs is due to exposure to contaminants in well water, this potential hidden financial burden further articulates the need for water quality monitoring.

Our study was intended to look at what would be the best business/financial model to conduct well water monitoring and testing.

Questions emerged:

- Should the testing be done by the private sector? If so, is it financially feasible?
- Should well water monitoring and testing be done by the government? If so, how do you ensure compliance?
- What does a cost/benefit analysis show us if government becomes more actively involved in the testing and monitoring of private water wells?
- What is the business case for establishing well water monitoring and testing in Newfoundland and Labrador?

Our long term goal was the have a functioning lab in this province, providing affordable and accessible and high quality water testing facility to the communities. We believed that this study would give us proper direction to establish the lab and to make the venture sustainable – either publicly or privately funded. As a result, the study used a mixed method approach: one to one interviews, focus group discussions, feasibility study of existing technologies, and content analysis of available case studies.

Objectives
This research approached the identified problem through three main pillars. The first pillar was to assess and articulate the public health risk. Analysis of available public source water quality monitoring information was used to create a proxy model for the public health risk. In addition, a summary of the potential health risks from exposure to ground water chemicals found in Newfoundland and Labrador was also included.

The second pillar was a population perspective provided by interviews conducted with well owners, representatives from municipal and provincial government, laboratory professionals and medical professionals. Because of the demographic disadvantages known to private well owners in the province, such as an aging population, and access issues due to rural areas, one-on-one interviews with well owners were extremely important for identifying barriers and challenges. Key messages from these interviews help to inform the solutions, and address what the problem on the ground with the people who will be looking to utilize this service.

Finally, the third pillar was a business model for approaching a solution: a water quality monitoring service in Newfoundland and Labrador. This high level model includes financial projections, as well as estimates for required analytical equipment. This model was presented as groundwork evidence for future entrepreneurs to use to develop such a service in Newfoundland and Labrador. This water quality monitoring service would be an important factor in addressing this public health issue, ensuring safe drinking water and providing a sustainable solution in the province.

Thus the project had three objectives:

1. Assessing the public health risk from exposure to contaminants in Newfoundland and Labrador private well water using secondary data available on public water wells.
2. Provide a population perspective through one-on-one interviews across the province.
3. Explore solutions and propose a business model for a water-testing laboratory that addresses the public health risk and present service gap.

Theoretical Approach

- There was an urgent need to establish the affordable and accessible water quality monitoring services with all required facilities. The latest nationwide survey (2011) by Ecojustice showed that the province ranks behind four other provinces in Canada. It was believed that the new water quality testing services would significantly improve overall status of the province by incorporating the deprived section of the community. In turn, this would ensure health promotion and reduction of impending disease burden and eventually saving scarce financial resources. How this was reflected at an individual well water owner level has been unknown and one of the purposes of this research was to reflect both the community and individual level implications of having effective water quality monitoring services.
- We explored possible options and carry out an in-depth financial analysis based on models such as a centralized lab in St John’s with time bound collection facilities with the communities or decentralization of the lab network; establishing labs in strategically located cities like St John’s, Corner Brook, Gander, Goose Bay. As indicated in our letter of support, a strong partnership with Municipalities NL (including previous research

work on municipal infrastructure risks) helped to provide access to many municipalities and households, which in turn helped to develop proper marketing strategies in order to raise demand for the service.

- From a business model standpoint, we examined barriers and critical success factors in sourcing possible investors, cost recovery, quality control, and the merits of dealing with other potential customers like industries. We also explored the essential regulatory requirements getting national accreditation and thus we were able to garner support from the provincial government.

Research Plans and Methods

- The research plan was a mixed methods approach focused primarily on qualitative methods including: one to one interviews, focus group discussions, feasibility studies of existing technologies, and content analysis of available case studies.
- In the first instance, we approached Municipalities NL and sought support to carry out an issue identification session with members. Secondly, we selected a small number of municipalities in the province and carry out in-depth discussions with subject matter experts communities (such as Town Managers and Engineers) and some key informant interviews (such as the provincial government, industries (manufacturers of analytical technologies), laboratory operator and prospective institutional partners). We conducted telephone interview of individual well owners of some communities of east and west coasts of Newfoundland.
- Third, we will carry out detail analyses of technical and high-level financials specifications of instruments, transportation, human resources etc including a cost/benefit analysis. Finally, we will examine appropriate business model to rank the best practices and provide recommendations for the most sustainable financial model to conducting water quality monitoring services.

Health Risk Modeling

First, a proxy model for the health risks from potential contaminants in private wells in the province was created using available secondary data. This model is similar to the spatial model proposed in the white paper by the Drinking Water Exposure Group of the California Department of Public Health for situations in which there is not data available for a given set of wells, and a nearest neighbor model cannot be employed (Vanderslice et. al, 2006). In such an instance, estimates can be made on a regional scale, based on available ground water quality data, as was done on the provincial level here in Newfoundland and Labrador.

The Newfoundland and Labrador Water Resources Portal is an online resource providing information on public water supply type, location, source, and the population serviced by the water supply. In the province of Newfoundland and Labrador, there are 179 public water groundwater wells that supply 88 communities serving a population of approximately 39,339. Samples at both the water source and tap are regularly taken and tested by the Department of Environment and Conservation of the provincial government to monitor this water quality, and these results are published through the Water Resources Portal. Reports on private water supplies, such as wells, however are not published, because these sources are not monitored. For this reason, the public water quality reports present the best data to estimate the risk to private well owners and are used to create a proxy model. Focusing on public water systems supplied by groundwater wells, a scan of available public well source water quality reports assesses the potential risk to private well owners in the province. Tap water test results are not included in this model, because of the potential confounder of contamination within home plumbing systems, and to avoid any bias that may be added by removal of contaminants by water treatment.

Included in this present study are 2,292 public well source water quality reports of tests ranging from September 23, 2001, to July 11, 2013. Through this process, key contaminants have been identified to be in excess of the Health Canada Guideline values (GCDWQ) for toxic chemicals. These contaminants are arsenic, barium, cadmium, chromium, lead, mercury and selenium. A review of the literature summarizing the health risks from these contaminants is presented in section 1.2.

Population Perspective – Interviews

Having identified and articulated the risk, the next step was to develop and explore potential solutions to decrease this risk and address the service gap. Interviews and conversations with representatives from key groups in the province were conducted. These conversations provide a glimpse into the public perception of need, and qualify the demand for water quality monitoring through qualitative data.

A stakeholder model with a regional distribution was used in the sampling approach to the interviews conducted. Firstly, Municipalities Newfoundland and Labrador was approached and an invitation for participation was put out to representatives of communities with a large percentage of private wells. In the case of municipal representatives and medical professionals, these interviews were conducted with at least one participant from each of the three main regions of the island (east, west and central). A summary of interviews performed is presented in Table 3.

Table 3. Summary of Interviews Performed

Stakeholder Demographic	Number of Interviews
Government Representatives	6
Health Professionals	4
Laboratory Professionals	4
Total	19

Interviews were analyzed for high-level themes and issues of barriers and challenges for water quality monitoring in the province. In addition to barriers and challenges, interviews with laboratory professionals were used to inform requirements for analytical equipment in a laboratory testing facility. This technical data provides a key costing estimate for the presented business model.

We conducted telephone interview of individual well owners of some communities of east and west coasts of Newfoundland. The interviews were conducted by the professional interviewers. We contacted Info Canada and requested for all the residential telephone numbers they had on file under these community names. We recruited 80 interviewees (37 from the Eastern and 43 from the Western part). Upon completion of the questionnaire survey, necessary coding was done, and data were entered into a spreadsheet using SPSS software. All the researchers checked the data sheet and data cleaning was done where needed.

Business Models – Water Quality Monitoring Service
A business model for a water quality monitoring service based on a centralized laboratory model is presented. This model is intended as groundwork for future entrepreneurs to pick up and take forward to develop such a service in the province, or in similar regions elsewhere. Three sensitivity models, based on varying levels of legislative support are explored. Estimated financials for the most reasonable model are included here, and financials for the other two models are included in the online supplementary documents. The business model presented is based on the introduction of a mandatory testing requirement for all private well owners. While this mandate is introduced, the requirement is not enforced in any way. Since this requirement is not enforced, a 25% compliance rate is assumed.

Sustainability of these models is a key consideration, and therefore contains projections for growth, depreciation of equipment, and other cost aspects, which are elaborated on in the notes on the financials.

Ethics Clearance

Health Research Ethics Authority (HREA) approved (#13. 193) the project on Aug 22, 2013.

Results and Discussion

Health Risk Proxy Model

Our results show toxic levels of arsenic, barium, cadmium, chromium, lead, mercury and selenium have been found in past public supply groundwater source tests. Contaminants were found in a wide range above the guideline value. These results are summarized in Table 4.

Table 4. Distribution of toxic chemical contaminants found in excess of Health Canada Guideline values in public supply groundwater sources in NL

Contaminant (Health Canada guideline value mg/L)	Total number of test results in excess of Health Canada guideline value	Exceedance range (mg/L)	Number of communities with contaminant in excess (percentage of communities, n=88)	Number of public wells with contaminant in excess (percentage of wells, n=179)	Number of private wells potentially contaminated (proxy model)	Population potentially at risk of contaminant exposure (proxy model)
Arsenic (0.01)	43	0.011-0.044	11 (12.5)	16 (8.9)	3,560	8,544
Barium (1.0)	7	1.03-1.66	2 (2.3)	2 (1.1)	440	1,056
Cadmium (0.005)	1	0.0056	1 (1.1)	1 (0.6)	240	576
Chromium (0.05)	1	0.1	1 (1.1)	1 (0.6)	240	576
Lead (0.01)	41	0.011-0.183	18 (20.5)	21 (11.7)	4,680	11,232
Mercury (0.001)	1	0.0021	1 (1.1)	1 (0.6)	240	576
Selenium (0.01)	2	0.012-0.023	2 (2.3)	2 (1.1)	440	1,056

Of the contaminants found, the data was analyzed to examine the distribution of contamination as a portion of the number of communities with public well groundwater sources. This data came from a total of 88 communities, with a total of 179 distinct water supplies. This discrepancy in numbering is due to the presence of more than one water source in some communities. These results are summarized in Table 1, and percentages of both number of communities, and number of water supplies, or wells, are included.

All of the seven chemicals found in excess of the Health Canada guideline values pose serious potential health risks. However, of particular concern is the portion of water supplies having shown arsenic (9%) and lead (12%) contamination. Given that there are 40,000 wells in the province, this proxy model suggests a large number of wells that could potentially be contaminated, as is presented in Table 4. The combined public health burden suggests that 9, 840 wells are potentially contaminated.

According to the 2011 census, the average household size in the province of Newfoundland and Labrador is 2.4 persons (Statistics Canada, 2013a). Assuming that private wells are generally one well per house the population potentially at risk is also presented in Table 4. This model represents a risk from drinking water contaminants to 23,616 people, or 4.7% of the province's population (Statistics Canada, 2013a). In Newfoundland and Labrador, 14.5% of the population are children aged 14 or younger (Statistics Canada, 2013b). Therefore, this model also represents a risk of exposure to drinking water contaminants to 3,424 children in the province. This is of particular concern from a health perspective; since children are more susceptible to health impacts from drinking water contaminants, especially lead (ATSDR, 2015).

These test results represent source water tests for public supplies, before any treatment facility is reached. It can be assumed that publicly administered water receives appropriate treatment at the facility to make this water safe for public consumption, though more research should be done to quantify and further understand the interventions taken. The real concern presented by this data is to residents of the province drinking ground source water from their private well. Since these water supplies are not tested for physical or chemical parameters, it is not known whether this water is safe to drink. Given that most private well owners do not have expensive water treatment systems installed at home, especially for physical and chemical parameters, it is reasonable to assume that these numbers represent a proxy of the potential risk to private well owners in the province.

Not all communities have shown evidence of just a single contaminant. The health risk to the public is further added to by the presence of multiple contaminants in some communities. Six communities with public wells showed multiple contaminants like arsenic with chromium, or lead with arsenic, barium, cadmium or mercury.

Proxy Model Limitations

There are some limitations associated with the proxy model and assessing estimating the public health risk. Public supply source water data is used in place of private supply source water tests because this is the best available information. This emphasizes the need for regular water quality monitoring of private water supplies, so as to ensure an acceptable level of risk to public health. The population calculations of the model are also based on census data that is averaged for the entire province, on the assumption that one well serves one household. Given the presence of community wells that often serve multiple families, this estimation might actually present a figure less than the actual number of people at risk.

Interview Results: Barriers and Challenges to Water Quality Monitoring
Attempting to implement adequate water quality monitoring service for private well owners in the province presents its own unique set of challenges and barriers that must be overcome. Interviews were analyzed and high-level themes were identified. These themes were organized into a series of potential barriers and challenges from two perspectives: that of the well owner looking to utilize the service, and that of the service provider looking to establish a water testing laboratory. Figure 1 and Figure 2 (page 15) show a summary diagram of these barriers and challenges as perceived form the perspective of individual well owners, and laboratory administrators, respectively.

Figure 1 Water Quality Monitoring Resident Barriers and Challenges

Community perceptions of water quality:
Participants had mixed response about the water quality of their private wells. Most of the well owners (76%) were satisfied (37 in Western vs. 24 in Eastern) with the quality of their drinking water. Some households (25%) were so confident about the water quality that they had never tested their well water. In general, the communities seemed very sure of that water sources, were safe as there was no reported outbreak. Even some wells (18%) were tested for contaminants only once in a lifetime due to the good physical appearance or colour or lack of bad taste or absence of any significant water-borne disease in the family. Some people believed that the presence of sand around the well would act as a physical barrier to the contaminants but few residents along the sea coast believe that drinking water is salty, and it can create some health problems.

Water Testing:
Most of the participants (65%) who had tested the water, did it from the Lab of Service NL. Some people did it from private labs and some people from multiple labs. 28% participants tested the well water for bacteriological contaminants whereas, 13% tested for chemical

contaminants. Only 10% participating residents tested for both bacterial and chemical contaminants. Most of the people were found unaware of what type of testing done. Tests for chemical contaminants were not carried out because of the very high cost and unavailability of the testing facility within the province. These were the two most mentioned reasons by the participants that made the chemical testing difficult and challenging for them.

Figure 2 Water Quality Monitoring Laboratory Barriers and Challenges

Almost all of the participants (95%) thought that chemical testing of the private well was significant. Because inhabitants of some areas had heard about the high level of arsenic in drinking water. Some others were worried about some other health concerns regarding high level of chemicals in water like, nitrates, sulphur, fluorides. Few participants mentioned that they knew it was important but why they did not know. 6% residents mentioned that they wanted to test the water just for peace of mind.

Almost half of the participants (55%) reported of free service for water testing. One-fourth participants were not sure about the exact amount of money they paid. Because, somebody else paid for the testing of the wells, or they were the new residents of the houses.

Interestingly, most of the participants (74%) wanted to pay from their own money for the water testing. 18% people were not ready to pay, and the rest of them simply did not know their answers. Some participants thought that they did not have enough money for remuneration and other mentioned that the Government and Municipality were responsible for the payment. The most diverse answers we got from the participants when we asked them how more ready to pay. 18% participants wanted to pay around 20$, and only 5% participants wanted to pay 50$ or more. Some people mentioned they had no idea, or they were not sure about the amount.

Most of the participants (94%) agreed that a publicly funded chemical testing lab within the province would help to improve the monitoring the well water quality. They thought that easy accessibility (93%) and low cost (50%) would make the use of the laboratories easier for them. Some of the participants (18%) proposed the lab should be centrally placed in the province, but the sample collection units should be in every local community or at least in nearby towns. Some others think that the labs should be decentralized (8%) and several labs (7%) should be established in different cities and big towns of the across the province. Several others (5%) recommended for mobile labs. Few participants (5%) thought that pick up service from houses would be the best. Almost everybody agreed that easy accessibility and low and affordable cost should be the main considerations in establishing a successful lab system.

Two-thirds of the participants (74%) were in favour of having multiple partners in running the proposed laboratories. 73% of the participants thought that Municipal Government, Provincial Government and Private Partnerships would be the major contributors. Others added Local Community (12%), Environmental Agency (15%) and Public Health Department (35%) in variable combinations with the organizations as mentioned earlier. Few participants (5%) said they were not sure about the exact combination of the partners though they thought more than one organizations were necessary for successful running of the laboratories. The participants were asked for any suggestion to make the laboratory sustainable. Nearly half of them (42%) recommended for Government subsidy. 15% people wanted the laboratories in multiple locations, not merely in St John's. Some of them thought Private partnership (3%) or local Municipality (5%) would be essential for sustainability. Interestingly, 40% of the participant mentioned public awareness was the most important factor to make the laboratory system successful. A substantial number of participants (21%) felt other measures like medicated kit usage to decontaminate the water at residential places would be more useful than just a laboratory for chemical testing of private well water. But most of them (79%) mentioned that laboratories would do the purpose effectively.

Most of the participants of the telephone survey were female (66%) aged between 50 to 59 years (30%). They had completed High school (36%) or a community college (31%) degree. Half of them (51%) were still doing jobs or self-employed. 53% participants were from West Coast and the rest from Eastern part of the province. But there were no significant difference in the answer pattern among them. In both region of the province participants had almost same type of perception about the water testing and establishing a new chemical testing lab.

Public Education

While each of these identified issues is significant, public education bears special consideration for discussion. There are at least 14 drinking water parameters that may have direct health impacts on individual well owners. These parameters may be microbiological, physical or chemical in nature. Furthermore, these parameters may be considered contaminant or aesthetic according to the Health Canada Guideline for Drinking Water Quality (2012). These multiple levels of distinction, and the potential presence of so many different contaminants illustrate the complicated nature of ensuring safe drinking water. For the average layperson, this is a challenge that requires more time, and energy to understand than is available. There is a large perceived gap in public education, as came through in the interview conversations with both well owners and municipal representatives. "The biggest thing if this [laboratory] is going to be set up is an education campaign so that we can explain why it's being done and why it should be done… anything to help get the message across."

It is popular to believe in Canada that drinking water is safe, and that the supply is unlimited. The public lacks understanding of potential risks from waterborne contaminants

(Hexemer, 2002), procedures for proper testing (Jones, et. al, 2006), and of practices for proper well maintenance (Simpson, 2004). Potential campaigns through television, the internet, and delivered print media should be mounted to address the deficit of understanding surrounding water.

In the very least, a public education campaign around water quality, potential contaminants, and testing services available is necessary. This will be doubly true when coupled with the above recommended legislation change. The public will need to understand not just why water testing should be an important regular habit, but also what services are available for the public to use. A well conceived marketing plan would need to be partnered with the rolling out of any new services, to ensure adequate use.

While the key service gap is in the actual testing and monitoring services available, public education is also another large problem. Understanding the distinct differences between the potential contaminants in the water, whether they are microbiological, inorganic, or chemical is complicated for a layperson. Furthermore, understanding the treatment methods available is even more challenging.

In one experiment in Southern Ontario, even when testing bottles were delivered to the door less than 50% of households responded (Hexemer et al., 2008). Despite the convenience provided by this study, the response rate was still low. This further emphasizes the need for public education in Canada, and testifies to the public attitude that water quality is not a concern, despite evidence to the contrary in the literature (Ritter, et. al, 2002). If the public truly understood the potential health risks, better stewardship or private wells would certainly ensue (Kreutzwiser et al., 2011).

Business Model

Further to the challenges brought up in conversation with individual well owners, specific challenges were addressed through conversations with laboratory professionals that are of key relevance in attempting to establish water quality monitoring service. Each of these particular issues is explained to help inform the business model.

Sample Volume

The private laboratory professionals interviewed for this study expressed concerns over the long-term viability and profitability of a laboratory dedicated to drinking water testing in the province. The primary concern was number of tests per year in order to sustain such a venture, and provide an appropriate return on investment made. In particular, it was felt that without a government mandate requiring testing, not enough tests would be submitted per year based on the current climate of public opinion towards well water in the province.

Maintenance

Water testing is an important service that must be performed reliably. Each laboratory professional interviewed stressed the importance and need for proper maintenance of equipment, and all stated that they used the manufacturer’s service contract for laboratory equipment. However, this is a significant cost, with contracts running over $20,000 for a single ICP-MS unit.

Administrative Costs

Administrative overhead can be a significant cost of an operation. One laboratory interviewed explained that each invoice created costs the company about $125. Included in this cost is creating the invoice, billing, banking, data entry, etc. In the case of a model for a potential laboratory solution in Newfoundland and Labrador, this could be a significant deterrent if each individual well owner was invoiced. Furthermore, the challenge of collecting revenue on each of these individual invoices magnifies the potential for cost. This laboratory suggested that the client should be one entity, say for example, the provincial government, to alleviate these costs and streamline the process. It was estimated by the same laboratory that the administrative overhead cost could be reduced to about $50.

Insurance

Safe drinking water is a key aspect of health, and offering testing services to declare that water safe to drink is an important service. Commercial liability insurance is an important cost consideration when dealing with such an important aspect of individual health, and will represent a significant cost. Individual well owners will need to be able to rely on the report that they receive, and backing up these claims will require sufficient insurance coverage.

Invoice Lag time

Should the invoices be made to individual well owners, there is an administrative challenge and cost associated with collecting on numerous, relatively small invoices. This currently is a deterrent to private laboratories in pursuing and promoting drinking water testing.

There is a potential hurdle however in submitting a bid to government as well. To submit a bid to the provincial government, one must already have the equipment and accreditation. According to one private laboratory, "This is a $500,000 investment just to bid, with no revenue collected for almost a year." Guarantee of getting the contract is also a deterrent here for private laboratories. Partnership with government on moving forward with creating a testing laboratory will be an important aspect of ensuring the entrepreneurial success of this venture.

Accreditation Fees

Accreditation is an important part of ensuring quality and best practices in an established laboratory. Two accreditation bodies the Canadian Association for Laboratory Accreditation (CALA), and the Standards Council of Canada (SCC), exist in Canada as options specific to laboratory accreditation. There is a significant cost however associated with the accreditation process, including annual fees. Furthermore, regular retesting is required to keep accreditation status up to date. One laboratory estimated yearly accreditation fees for drinking water parameters to be between $20,000 and $30,000.

Reporting Challenges

Results of water tests performed must ultimately be delivered to the individual well owner. As previously mentioned, water quality reports, and the intimate understanding of the associated risks from specific contaminants is quite challenging to the average person. Therefore, the responsibility for the interpretation of the results and recommendations made thereafter is an important question. In the event that a water quality monitoring service that is publicly administered is established, perhaps a partnership with the Department of Health and Community Services, similar to the interpretation already offered in the province for microbiological testing would be most valuable. However, as reports become increasingly complicated, and deal with several parameters including metals, recommendations for treatment options become a challenge. Department of Health and Community Service employees are committed to serving in the best interest of the public, but cannot be seen to show favoritism in recommending specific commercially available treatment options. This is an important consideration.

Sensitivity Modeling

There are several ways that a water quality monitoring service can be rolled out, and the main variable between these scenarios is varying levels of legislative support from in this case, the provincial government. One could imagine that the provincial government may recognize this public health risk and meet it with a very strong mandate. Such a response would see the introduction of regular, mandatory water testing for all individual well owners, with some enforcement to support the policy. For example, should certificates not be presented every two years, homeowner's insurance would be blocked for the well owner. This kind of strong legislative support, assumes 100% compliance from all private well owners in the province. While financial projections show this scenario to be wildly profitable based on a modest price to service users, this scenario is not considered likely to occur given the current political climate in the province.

A second sensitivity model can be imagined in which one introduces a water quality monitoring service without any support from the provincial government. Given the voluntary nature of sample submission, 1000 samples are assumed to be submitted in the first year. However, even when a 10% growth rate for the first three years is explored, this model is not shown to be sustainable and will fail.

Thus, the business model presented is based on a scenario in which mandatory testing requirement is introduced by government, but not enforced. This model is further elaborated on in the following financials.

Financial Modeling

This financial model is based on a mandatory testing requirement that is not enforced. Even though the testing is considered required, there is no enforcement for non-compliance. A 25% compliance rate is therefore assumed for in this forecasting model. Three year sales projections are presented in Table 5. Given the assumed 25% compliance rate, 6,250 samples are assumed in the first year. Given that news of the service will spread via word of mouth and a public education campaigning, a 10% growth rate for the first three years is projected. The price for a full suite of testing is set at $100, based on support of this price in interviews with private well owners. Furthermore, a service of individual parameter monitoring is offered to residents who require additional testing, more often than the biennial schedule, due to a known problem with an individual contaminant. The price for this service is set at $25, and the volume of testing is assumed at 10% of clients.

Table 5: Financial Model – Sales in CND $1000

Sales	PROJECTED		
SALES ACTIVITIES	**Dec-16 (%)**	**Dec-17 (%)**	**Dec-18 (%)**
Well water chemistry analysis	625 (98)	687.5 (98)	756.25 (98)
Individual Parameter Monitoring	15.625 (2)	17.188 (2)	18.908 (2)
TOTAL SALES ($)	**640.625**	**704.688**	**775.158**

ASSUMPTIONS REGARDING SALES

Scenario is based on introduction of mandatory biennial testing of drinking water (unenforced) with a voluntary 25% compliance. 6,250 samples first year. $100 per testing suite.
Assumes 10% growth in samples per year, based on word of mouth and public health information campaigns.
Individual Parameters refers to clients with known risk to specific contaminant, requiring specific testing. Estimated at 10% of clients. $25 per parameter.

Expenses for this model are presented in Table 6, outlining the costs of sales and Table 7 outlining the operational administrative expenses. As this scenario assumes a 10% growth rate in samples tested each year, material costs grow proportionately over the three-year projection. A three-year straight line depreciation of analytical equipment is assumed. Initial marketing funding is included as a roll out of the service, and then reduced in subsequent years. Expenses for maintenance, rent, utilities, shipping, interest as well as human resources are all assumed and elaborated on in the notes on the financials

Table 6. Financial Model – Expenses – Cost of Sales in CND $1000

Expenses - Cost of Sales	PROJECTED		
	Dec-16 (%)	**Dec-17 (%)**	**Dec-18 (%)**
Analytical Equipment Purchase	115.1 (34)	115.1 (34)	115.1 (34)
Sample Bottles	37.5 (11)	41.25 (12)	45.378 (13)
Argon	20 (6)	22 (7)	24.2 (7)
Total Material Costs ($)	*172.6*	*178.35*	*184.678*
Direct Labour Wages	120 (36)	120 (35)	120 (35)
Repairs & Maintenance	11.5 (4)	11.5 (3)	11.5 (3)
Services / utilities	28.8 (9)	28.8 (9)	28.8 (8)
TOTAL COST OF SALES ($)	**332.9**	**338.65**	**344,978**

ASSUMPTIONS REGARDING COST OF SALES

3 year straight line depreciation of analytical equipment assumed.
Sample bottles estimated at $6 per household.
Argon assumed at $20,000 for the first year, with a 10% growth rate.
Maintenance assumed at 10% of equipment cost.
Rent assumed at $2,000/month plus 20% utilities.

Table 7. Financial Model – Expenses in CND $1000

Expenses	PROJECTED Dec-16 (%)	Dec-17 (%)	Dec-18 (%)
Advertising	100 (25)	50 (14)	50 (14)
Shipping & Delivery	62.5 (15)	62.5 (18)	62.5 (18)
Total Sales Expenses ($)	*162.5*	*112.5*	*112.5*
Management Salaries	100 (25)	100 (28)	100 (28)
Office Salaries	50 (12)	50 (14)	50 (14)
Accreditation Fees	30 (7)	30 (8)	30 (8)
Office Expenses	2 (1)	2 (1)	2 (1)
Insurance & Taxes	15 (4)	15 (4)	15 (4)
Bank Charges	10 (2)	10 (3)	10 (3)
Interest on L.T.D.	35 (9)	35 (10)	35 (10)
Total Admin. Expenses ($)	*242*	*242*	*242*
TOTAL EXPENSES ($)	**404.5**	**354.5**	**354.5**

ASSUMPTIONS REGARDING EXPENSES

Initial marketing campaign introducing new service in first year. Reduced in subsequent years.

Interest assumed at 10%. $350,000 guaranteed government for initial equipment purchase.

Shipping assumed at $10 per sample.

The income statement, presented in Table 8, shows a negative balance of expenses over income in the first year. However, forecasted growth shows a minor profit in the second year. This prospect of a service that is self-sufficient, without government subsidy should be strongly considered by policy and decision makers, as well as future entrepreneurs. This suggests a sustainable solution to an important population health issue is possible when coupled with regulatory support form government.

Table 8: Financial Model – Income Statement in CND $1000

Income Statement	PROJECTED Dec-16	Dec-17	Dec-18
Total Sales	640.625	704.688	775.158
Total Cost of Sales	332.9	338.65	344.978
Gross Profit	*307.725*	*366.038*	*430.180*
Sales Expenses	162.5	112.5	112.5
Admin Expenses	242	242	242
Total Expenses	*404.5*	*354.5*	*354.5*
OPERATING PROFIT	**-96.775**	**11.538**	**75.68**

NOTES TO INCOME STATEMENT

While this model will lose money year one, three-year projections show a profitable venture.

Please note that this is dependent on reasonable compliance of private well owners and introduction of required testing from the provincial government.

Notes on Financials

Pricing

When considering a public service, especially with regards to health, pricing is an important concern. For the sustainability of the laboratory, some cost must be associated with the service. However, as was apparent in the thematic analysis of the interviews performed in this study, cost can be a major deterrent given the general lack of means of citizens in rural populations, and the lack of awareness of the necessity of this service. A price of $100 was therefore chosen for forecasting, as being a reasonable price that is quite competitive with prices found based on industry consultation.

Facilities

The centralized laboratory will require a facility from which to operate. It is recommended that this facility be established in a central location of the province, to provide the most convenient service. Rent is estimated at $2,000 a month based on prices in Grand Falls-Windsor. Utilities have been assumed at 20% of rent.

Analytical Equipment

As mentioned, the primary focus of the water quality monitoring facility should be the testing of contaminant parameters to protect public health. Some laboratory equipment is necessary as a baseline; for example, an analytical balance should be considered an important basic laboratory tool. Based on the above health parameters, the laboratory will require an inductively coupled plasma mass spectrometer (ICP-MS) with autosampler, an ion chromatograph, and a turbidity meter. These instruments were chosen based on consultation with industry professionals.

The following table presents estimated costs for analytical equipment by parameter area, based on conversations with industry suppliers.

Table 9. Estimated costs of analytical devices in CND $1000

Analytical Devices - Health Parameters		Analytical Devices - Aesthetic Parameters		Analytical Devices - Environmental Parameters		Analytical Devices - DBP's	
Device	Est. Cost	Device	Est. Cost	Device	Est. Cost	Device	Est. Cost
ICP-MS	180	pH Meter	0.5	Conductivity Meter	1	Gas Chromatography/ Mass Spectrometer	125
Auto sampler	20	Spectrophotometer	6	Discrete Analyzer	65	TOC	50
Ion Chromatograph	30	Ion Chromatograph	30				
Analytical Balance	2						
Turbidity Meter	10						
Total cost	242.8	Total Cost	36.5	Total Cost	66	Total Cost	175

An ICP-MS is a robust, workhorse style machine. Equipped with an auto sampler, this instrument can handle about 200 samples a day, with detection limits well below the Health Canada Guideline values for trace elements in drinking water. An ICP-MS requires argon to operate, and this is an important consideration from a cost and facilities perspective.

An ion chromatograph uses a column to separate ions and identify different ions based on detection peaks. As part of the health parameter suite, this ion chromatograph will be used exclusively for negatively charged ions. Negative ion dedication will save costs in terms of technician time and switching out columns. An ion chromatograph can perform about 60 tests a day. However, each sample run requires the setting of a concentration scale. If a sample contains many separate ions at a wide range of concentrations, the sample will need to be run under multiple calibrations to achieve useable results for each ion.

While the testing of health parameters should be the primary mandate of the facility, as mentioned, aesthetic parameters pose a value added opportunity for consumers. To complete the suite of aesthetic parameters would require a minor increase in capital cost. A spectrophotometer would be required to measure color, and a pH meter as well. Purchase of a second ion chromatograph dedicated to positive ions is recommended for cost and time savings, and for handling the volume of tests required.

Additionally required to perform these tests for environmental parameters is a conductivity meter and a discrete analyzer for analysis of agriculturally significant elements like phosphorous and nitrogen. The addition of this equipment would allow for a complete approach to water quality monitoring that incorporates data monitoring of the environment.

A possible later phase full integration of the municipal tests currently being shipped out of province would involve testing for disinfection by-products (DBP's). Because municipal water supplies are treated, disinfection by-products are an important testing parameter for municipal water supplies. This represents a significant expansion of equipment in the form of a purchase of a gas chromatography mass spectrometer, as well as further considerations for more staff.

Testing Schedule

While currently decisions around testing schedule frequency are at the discretion of the body having authority over a specific region, Health Canada recommends that private well owners have bacteriological testing done two or three times a year, especially after the spring thaw, after a long dry spell and after heavy rains. Physical and chemical testing should also be performed whenever contamination is suspected (Health Canada 2012).

Realistically, for the model proposed, it shall be seen that a complete water test completed once every two years will provide sufficient data to gather information on the potential health risks, as well as provide a sufficient volume of tests to ensure the sustainability of the testing facility.

Accreditation

Accreditation is an important, but expensive process, required by the Department of Environment and Conservation for drinking water testing. Fees here are estimated at $30,000 a year, based on conversations with industry professionals.

Insurance

Public liability insurance is estimated at $15,000 per year. This high estimate is based on the sensitive nature of ensuring public health and the reality that an error could have serious health consequences.

Human Resources

Staff is an important consideration for establishing and estimating laboratory costs. Based on the above model, the laboratory will require one director/manager level employee, one administrative assistant, and two laboratory technicians, one primarily responsible for health parameters and the ICP-MS, and one primarily responsible for aesthetic and environmental parameters and ion chromatography. It will be important that the director have experience as a laboratory technician so as to fill gaps created by vacation, or sick time of the two laboratory technicians. The director will also be considered to take on the necessary quality control portfolio required for accreditation.

Shipping

Partnership with the existing Services NL delivery system as used by the Public Health Lab for bacteriological testing is an important part of the functionality of this model. A cost of $10 for sample based on either pick up, or shipping by bus or courier is factored into the forecasting. There is further opportunity for exploring partnerships with municipal governments in the province to help alleviate shipping costs, as well as aid in the testing schedule. For example, if all the tests from a given community are submitted at a single time, gathered and delivered by a municipal employee, greater organization and regulation of the testing schedule can be maintained.

Marketing

In each of the above scenarios, marketing is an important part of service use. Advertising of the service will help growth, and in sensitivity models 1 and 2, promote the new testing regulations. There is an important added benefit for public education and public awareness that should be considered when creating the advertising campaign.

Laboratory Costs

Estimates of the cost of important laboratory supplies like argon and sampling bottles are included. The price of sampling containers is based on bulk ordering of snap tight sampling bottles, and the inclusion of a small ice pack for shipping.

Other Costs

Other costs like loan financing, and office expenses are also included to help make the financial forecasts as realistic as possible.

Environmental Data Tracking

The installation of a water quality monitoring service provides an opportunity for more than just the health of individual well owners. Currently, environmental and water quality data on a provincial scale is lacking. The establishment of an in province facility like the one posed in this study provides the opportunity to begin a system cataloguing and documenting the results of water quality tests for private wells in the province. This will provide a dataset that can demonstrate long-term trends in the environment in the province. There will be value for government in terms of environmental and public health data, as well as a valuable source of information for researchers. This system would build on the commitment of the Department of Environment and Conversation to provide total transparency with information, as is currently demonstrated through the Water Resources Portal.

Legislative Implications

Currently, regular testing regimes are only mandatory for public water supplies, and private water supplies are not regularly monitored. A drilled well is required to be tested for total coliforms and fecal coliforms (*e.coli)* at the time of installation, and then is allowed to continue indefinitely (DOEC, 2013b). This lack of profiling on the mineral content of the water, as well as any regular monitoring over the life of the well is a potential health risk.

Policy should be introduced requiring the regular testing of private water supplies in the province. Regulations around the maintenance and monitoring of private supplies similar to those required of public supplies should be put in place, even if on a reduced scale. It is recognizable that weekly submission of water samples from private wells is not reasonable to expect, but a complete biennial test of the water would not be considered unreasonable, and would be a significant improvement to the existing health risk and monitoring gap.

Taking the lead on this kind of issue is necessary for the introduction of a water quality monitoring service to be successful. A strong mandate from the government requiring testing would send a message to residents that clean drinking water is important, and that the risk to public health should be taken seriously. Ultimately, this would be one of the fastest catalysts at improving public education around drinking water quality and health.

Ethical Implications of this Study

The greatest ethical implications surrounding this problem lie with inaction and maintenance of the status quo. Currently, a large portion of the population is not receiving adequate access to water testing service to ensure safety and good health.

Access to safe drinking water is a human right established by the United Nations. Furthermore, it is a constitutional right in Canada under Section 72 of the Charter of Rights and Freedoms. There is an ethical obligation to act to address the identified gap and ensure public health.

A potential ethical hurdle that might be faced is in the introduction of legislation requiring private well owners to have water tested. For starters, making this testing easily accessible and available free of charge will help deter public resistance. A counterargument to the introduction of the legislation might have to do with the government infringing on individual liberties in requiring tests. These tests would be no different than those performed on public water supplies to guarantee safety. Water quality is a complicated issue and difficult for a layperson to understand fully. It is recommended that in extreme cases of strong resistance, the government be willing to entertain applications for exemption from the required testing procedures, if adequate cause and explanation can be given.

Conclusions

Water is essential to life. Complete and regular testing should be done for all sources of contamination, inorganic or microbial. In the coming years, fresh water will globally be one of the most valuable natural resources, and the time is now to take action to ensure the sustainable protection of our water supply, for the health of the residents of Newfoundland and Labrador. The three main pillars of this original research study identify the risk using available secondary data, provide a population perspective on the issue through one on one interviews with key representatives and ultimately provide a business model to address the identified service gap through introduction of a water quality monitoring service.

The proxy model finds 3,560 wells and 8,544 people at risk for exposure to toxic levels of arsenic, 4,680 wells and 11,232 people at risk of exposure to toxic levels of lead, and 1,600 wells and 3,840 people at risk for exposure to barium, cadmium, chromium, mercury or selenium. In total, this model shows 23,616 people, or 4.7% of the province's population at risk of exposure to toxic drinking water contaminants. This is a hidden risk that is not only a public health burden, but also has financial implications for the cost of treatment and disease. Public water supplies are monitored and have mechanisms in place to ensure public safety. Engineering solutions exist to remove these contaminants from private household water supplies, however, because of a lack of data, these measures are not taken. With increased risk for cancer, cardiovascular disease, kidney damage, diabetes, neurological damage and developmental disorders, quality of life for residents of primarily rural parts of the province is a potential issue. These risks are avoidable.

The barriers and challenges identified in this study lead to some further key recommendations. A public education campaign should be mounted to raise awareness of the importance of water quality monitoring, as well as potential health risks from exposure to drinking water contaminants. Budgetary allowance for this education campaign is included in the financial modeling for the water quality monitoring service business model.

A model for the establishment of water quality monitoring service, and specifically a water testing laboratory is presented. Thematic interview analysis has informed the model and revealed barriers and challenges that must be overcome. Quantitative information, including detailed financial models further illustrates solutions to the service gap currently existing. This model shows that when coupled with legislative support and a modest price of $100 for a full testing suite, a sustainable solution exists to an important public health risk.

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Appendix 1

Focus group discussion – points:

- What is your opinion on water supply in your community?
- Are you happy with your own well/spring water? Why?
- What is your opinion on quality of your water?
- Do you test regularly?
- Do you think water monitoring is essential? If yes/or no, why?
- What do you think the major challenges of water testing in your community?
- Do you think that a water testing laboratory will help you to monitor your water quality?
- What are your suggestions on making the laboratory most effective, in terms of affordability and accessibility?
- Who can be the major partners in running the laboratory?
- How to make the laboratory most effective and sustainable?

Key informant's interview – points:

- What is your opinion on water supply in this province, particularly the areas deprived on public supply?
- What is your opinion on quality of water of private sources, such as wells, springs, ponds etc?
- Do the communities depended on own wells, test the water samples regularly?
- Do you think water monitoring is essential? If yes/or no, why?
- What do you think that the major challenges of water testing in those communities?
- Do you think that a water testing laboratory will help you to monitor the water quality in those communities?
- What are your suggestions on making the laboratory most effective, in terms of affordability and accessibility?
- Who can be the major partners in running the laboratory?
- How to make the laboratory most effective and sustainable?