Estimating the Economic Value of Drinking Water Reliability in Alberta

by

Alfred Appiah

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Department of Resource Economics and Environmental Sociology
University of Alberta

ABSTRACT

The overall objective of this study was to provide an estimate of the monetary value of drinking water reliability in Alberta. The study employed the results of an Alberta-wide survey on drinking water reliability. The survey elicited respondents' experiences with, and risk perceptions of, three types of water outages. Respondents who expressed positive risk perceptions were presented with alternative programs that reduce their risk perceptions to specified percentages, but increased their water bills. Using cost and other program attributes as explanatory variables, a random effects probit model was employed to measure the probability of supporting the programs and to account for unobserved heterogeneities that may be present in the sample. Kristrom's simple spike model was also used to account for "indifference" to the valuation scenarios. A control function approach was used to account for the potential presence of endogeneity in the absolute and subjective risk reductions of water outages using the respondents' perceived risk of internet outages as instruments. The survey results indicated that respondents have not experienced many water outages in the last 10 years, but expect significant percentages of them in the next 10 years. Using parameter estimates from random effects probit models for respondents with positive risk perceptions, we calculated a mean willingness to pay (WTP) of $71 per year for at least a 50% reduction in the likelihood of a short-term water outage. Results of the spike models for all respondents, regardless of their risk perceptions, indicate a WTP of $46 per year for at least a 50% reduction in the risk of short-term water outages. Results of control function mixed logit models showed that, given the chosen instruments, short-term absolute risk reductions are endogenous in the models. Controlling for endogeneity slightly increases welfare measures by about 7%.

DEDICATION

To my mum, Theresa Gyapong

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CHAPTER ONE: INTRODUCTION

The overall importance of good quality drinking water to human health cannot be overemphasized. The reliability of drinking water, defined as the availability of good quality drinking water all the time, is therefore an important objective of every government agency, non-government organization or business tasked with the provision of drinking water. For instance the Government of Alberta launched its *Water for Life* strategy in 2003 to ensure the provision of safe and secure drinking water for its residents in order to achieve a sustainable economy (Alberta Environment 2003).

The vast majority of drinking water in Alberta originates from the forested Eastern slopes of the Canadian Rocky Mountains (Emelko et al. 2011; Bladon et al. 2014). However, there are growing concerns that the increased severity and frequency of summer droughts and forest fires in regions like Alberta will lead to drinking water reliability challenges for communities. Forest fires also have negative impacts on downstream water quality (Emelko et al. 2011).

Natural science researchers have suggested forest and watershed management as a method of providing reliable and good quality drinking water in Alberta. The forest and watershed management practices include the placement of buffer strips along streams to reduce the amount of sediment and debris entering drinking water sources. They also include the reduction of the amount of hazardous forest fuels such as stands of dry trees in the watershed that can cause wildfires. These practices can potentially reduce risks to drinking water reliability and may be able to reduce the need for increased investments in drinking water treatment infrastructure. However, such treatments are costly and have to be evaluated relative to their benefits.

There are applications of such forest and watershed management strategies for managing drinking water supply in other parts of North America. For instance, in Denver, Colorado, the local water utility provider, Denver Water, has partnered with the United States Forest Service on a project called *From Forest to Faucets.* This project is aimed at improving forests and watershed protection over a 5 year period with particular concentration on watersheds that are critical to Denver`s water supply (Denver Water n.d). Improving forests and protecting watersheds can limit the impact of sediments on water reservoirs (Denver Water n.d). It can also reduce soil erosion and the risk of forest fires.

A key component of the benefits of the above forest and watershed management practices is the maintenance of the reliability of drinking water supply in Alberta. An economic analysis of benefits and costs of such forest and watershed management practices can inform investment decisions into such practices. In order to assess the economic benefits of forest and watershed management, it is important to know the value of drinking water reliability in Alberta. This value can be compared with the costs that will be incurred in the adoption of the forest management practices in a benefit-cost analysis. This approach will help inform investment decisions into either forest and watershed management practices ("green" infrastructure) or investments in traditional drinking water treatment ("grey infrastructure").

The overall objective of this study was to provide an estimate of the monetary value of drinking water reliability in Alberta using stated preference methods. Specifically, the study sought to;

- elicit Albertans' experiences with, and future risk perceptions of, water reliability challenges,
- elicit the trade-offs that Albertans will make between reduced risk perceptions of water reliability and increased water bills,
- examine how these trade-offs are affected by the proportion of respondents outside the contingent market because of a lack of perceived risks to water reliability using "spike" models and
- assess how these trade-offs are affected by the endogeneity of risk perceptions using the control function approach to endogeneity.

The study uses results of an Alberta-wide survey on drinking water reliability. The initial construct of the survey was tested using respondents who participated in three focus groups in different parts of Alberta in the spring of 2014. These respondents helped the researchers gauge how well the typical respondent would answer the questionnaire. A revised survey instrument was pre-tested through a pilot of 155 Albertans between January and February, 2015. The final survey was implemented by an Edmonton-based survey research firm that recruited respondents from its existing internet panel of potential respondents. A total of 1250 Albertans completed the survey. We also requested that the survey research firm oversample respondents from rural parts of Alberta because they tend to experience more water reliability challenges.

The survey collected information on numerical amounts of three types of water outages respondents have experienced in the last 10 years. The three types of water outages are short-term water outages, longer-term water outages and boil water advisories. Short-term outages in this context are defined as water outages lasting a few hours but less than a day. Longer-term outages on the other hand, last 2 to 3 days. Boil water advisories are issued by health agencies like Alberta Health services (AHS) either as a precaution or response to situations where harmful germs are suspected to be in drinking water supply. Analysis of the survey results indicates that respondents have experienced few water outages in the last 10 years. The average number of short-term water outages experienced in the last 10 years is 1. The average number of boil water advisories experienced in the last 10 years is also approximately 1. However, there is heterogeneity in these experiences in different locations of Alberta. On average, rural residents of Alberta have experienced twice the number of water outages experienced by urban residents. All these results testify to the current reliability of drinking water in Alberta.

The survey collected information of respondents' risk perceptions of the three different types of water outages discussed above. The results indicate that respondents expect significant percentages of water outages in the next 10 years despite experiencing few of such outages in the last 10 years. Respondents on average expect about 24% chance of short-term water outages in the next 10 years. They also expect about 9% chance of longer-term water outages and 10% chance of boil water advisories.

Survey respondents were also presented with alternative management programs that will reduce the risk of water outages but will lead to increases in their water bills. These programs were presented in both contingent valuation (CV) and a contingent valuation with more program attributes and different scenarios.[1] Joint parametric analysis was performed on the responses to both valuation questions. Random effects probit

[1] Throughout this thesis the contingent valuation with more program attributes and different scenarios will simply be referred to as "the hybrid valuation question".

models using respondents with positive risk perceptions showed an overall preference for management alternatives that will reduce risks of water outages to specified percentages but will lead to increases in water bills. However, the likelihood of support for such management alternatives decreases when the cost of the alternative is high. Kristrom's (1997) simple spike model was also used to model the dataset to include all respondents regardless of their risk perceptions. Finally the control function approach was used to account for the presence of endogenous variables in mixed logit models following Petrin and Train (2010) and Lloyd-Smith et al. (2014).

Using parameter estimates from random effects probit models, we calculated a mean WTP of about $71 per year for a management program that will reduce short-term risks of water outages by at least 50%. This estimate increases to $152 per year when respondents with less than 20% short-term water outage risk perceptions are removed from the sample. This is because such respondents may be indifferent between higher and lower risk reductions.

Parameter estimates from spike models that included all Albertans regardless of their water outage risk perceptions yielded a mean WTP of $46 per year for programs that will reduce water outage risks by at least 50%. Estimates from the control function mixed logit models indicate that short-term risk reductions are endogenous in our models, given the selected instruments. Correcting the endogeneity leads to slight increases in the marginal WTP for short-term risk reductions. All these WTP values are aggregated over the entire Albertan population to provide an estimate of the economic value of drinking water reliability. The values are also aggregated for different geographical locations in Alberta.

The study is organized into seven chapters. The following chapter presents a background on drinking water reliability. Major causes of drinking water reliability challenges are discussed. In addition the chapter presents a survey of some past studies that valued drinking water as well as electricity reliability. Chapter three presents the theoretical underpinnings of some econometric models used in the study. Chapter four presents an overview of the steps followed in the development of the survey instrument including descriptions of the focus groups and pilot studies that helped refine the initial survey. Chapter five presents a description of the survey data. Socioeconomic information of the respondents and their experiences with different water outages are presented. In addition the chapter presents the respondents risk perceptions of the three types of water outages. Chapter six presents a description of results from “spike” models, random effects probit models and control function mixed logit models. The chapter also reports all the welfare measures computed using parameter estimates from these econometric models. Finally, chapter seven presents a summary of the study, policy implications of the results obtained and some limitations of the study and directions for future research.

CHAPTER TWO: BACKGROUND

2.0 Introduction

This chapter provides background information on drinking water reliability. The major causes of drinking water reliability problems are discussed. The chapter also presents initiatives by water utility service providers in some parts of North America to reduce the impacts of forest disturbances such as forest fires on drinking water quality and reliability. In addition the chapter presents a description of stated preference methods that are used to value nonmarket environmental goods and services such as water resources. The chapter concludes with a survey of past studies that attempted to value drinking water as well electricity reliability.

2.1 Global drinking water quality and reliability challenges

Drinking water is one of the most important resources in the world, but there are challenges with access to good quality drinking water all the time. 11% of the global population have no access to reliable and improved water sources (WHO 2012). Although most of these water reliability challenges relate to developing economies, rural communities in developed nations are also vulnerable to such challenges (Pond and Pedley 2011). Such communities have to overcome increased costs associated with accessing high quality drinking water because of isolation (Pond and Pedley 2011). Similarly these communities may not have enough financial resources to fund capital and operating expenses on water treatment infrastructure (Pond and Pedley 2011). In such small communities, there may also be other competing needs such as housing and food for limited resources (Pond and Pedley 2011).

Water reliability challenges in developed economies are largely caused by excessive droughts, forest fires and insect infestations (Denver Water n.d.; Emelko et al. 2011; Bladon et al. 2014). This is because the vast majority of the drinking water in such economies comes from forested watersheds (Emelko et al. 2011). Approximately 67% of municipalities in the US obtain drinking water from forested watersheds (Bladon et al. 2014). Similarly 33% of the largest cities in the world such as Tokyo, Los Angeles and

Melbourne also obtain their drinking water from forested watersheds (Committee on Hydrologic Impacts of Forest Management 2008; Bladon et al. 2014).

Insect infestations can increase the risk of forest fire. For instance the Mountain Pine Beetles (MPB) has affected about 3 million acres of forest in Colorado since 1996 leading to increased risk of forest fires (Denver Water n.d.). Forest fires have negative impacts on downstream water quality and reliability through a combination of hydrological processes such as interception of precipitation and evapotranspiration (Emelko et al. 2011). They may release contaminants such as sediments, nutrients and heavy metals into watersheds (Silins et al. 2009; Smith et al. 2011; Bladon et al. 2014). In 1996, a forest fire burned about 12000 acres of forest in Buffalo Creek in the U.S. state of Colorado. A severe thunderstorm followed this forest fire in less than two months depositing about 1 million cubic yards of sediments into Strontia Springs Reservoir that supplies Denver Water's main treatment plant (Agnew, Lahn and Harding 2000). The forest fires led to the loss of soil cover which was responsible for reducing the impact of rains on the soil (Agnew, Lahn and Harding 2000). These loose particles were therefore easily carried into stream channels and impeded the flow of water in such channels as well as the quality of drinking water (Agnew, Lahn and Harding 2000). Apart from the impact of forest fires on water quality and reliability in Colorado, it also led to loss of lives and increased expenditure on fire suppression and emergency rehabilitation (Denver Water n.d.).

Again in 2002, the Hayman Fire burned more than 138,000 acres of forest in Colorado (Graham 2003). This forest fire led to changes in landscapes and increased the severity of flooding in four Colorado counties- Douglas, Jefferson, Park and Teller (Musiol and Ekarius n.d.). Debris from this forest fire was carried in to watersheds that were critical to the supply of drinking water in Colorado leading to negative impacts on downstream drinking water quality and reliability. Cities that obtained drinking water from the reservoir negatively impacted by these sediments from the forest fires spent about $25m to remove the debris (Musiol and Ekarius n.d.).

In 2003 the Lost Creek fire burned about 20,000 hectares of forest in the eastern slopes of the Rocky Mountains of Southern Alberta. This forest fire had significant impacts on drinking water quality and reliability in the upper Oldman River Basin

(Emelko et al. 2011). For instance the production of Nitrogen and Phosphorous in burned and the "post-fire logged" watersheds increased by 4-6 times after the fire (Silins et al. 2009; Emelko et al. 2011). A post forest fire analysis performed by Silins et al. (2009) also found that sediment production increased in the burned watersheds compared to the unburned catchments. Another effect of this forest fire on water quality relates to the release of trace elements and metals such as aluminium, magnesium, lead and molybdenum (Silins et al. 2016).

2.2 Initiatives to manage drinking water quality and reliability in developed economies

The impacts of land disturbances such as forest fires on watersheds that supply good quality drinking to municipalities have been outlined above. There are, however, initiatives in developed economies to protect these watersheds so as to maintain the quality and reliability of downstream drinking water supply. The following is a description of some of these initiatives

2.2.1 *From Forest to Faucets*: A partnership between Denver Water and the United States Department of Agriculture Forest Service

The Buffalo Creek and Hayman forest fires collectively cost the City of Denver about $237 million and also led to the loss of drinking water supplies (Edmonds, DeBonis and Sunderland 2013; Denver Water n.d). The city of Denver also spent about $10 million to restore drinking water supply after the forest fires but that did not reduce the production of sediments in the watersheds (Edmonds, DeBonis and Sunderland 2013). Hence instead of resorting to "short-term" measures to address drinking water quality and reliability, Denver Water decided to implement forest and watershed protection strategies (Edmonds, DeBonis and Sunderland 2013).

In 2010, Denver Water entered into a partnership with the United States Department of Agriculture Forest Service on a project called "From Forests to Faucets". Denver Water is matching the USDA Forest Service's $16.5 million investment, towards forest and watershed management over a five-year period with particular concentration on the watersheds critical to the Denver's water supply (Denver Water n.d). The City of Denver charges each resident a $0.14 fee per monthly water bill to support this project

(Edmonds, DeBonis and Sunderland 2013). The overall goal of this project is to restore about 33,000 acres of forests to ensure future drinking water quality and reliability (Edmonds, DeBonis and Sunderland 2013; Denver Water n.d).The USDA forest service is using Geographic Information System (GIS) to model and map land areas in Colorado that are critical to Denver’s water supply (Weidner and Todd 2011). The project is also aimed at identifying the forested watersheds that are critical to Denver’s water supply, and also identify those watersheds that maybe threatened by forest fires or insect infestations (Figure 1). Figure 1 shows the sub-watersheds where forest land areas are most important in protecting drinking water sources. Some of the land areas identified include the Upper South Platte River, South Platte Rivers Headwaters and Blue River watersheds, which are all the primary drinking water source areas in Denver (Adams n.d.).

The USDA forest service is undertaking restoration activities such as forest thinning and other ways of reducing hazardous forest fires such as stands of dry trees over the period of the project in the identified areas (Edmonds, DeBonis and Sunderland 2013; Adams n.d.). This will help limit the impact of sedimentation on reservoirs and other infrastructure through the reduction of soil erosion and the risk of forest fires (Denver Water n.d).

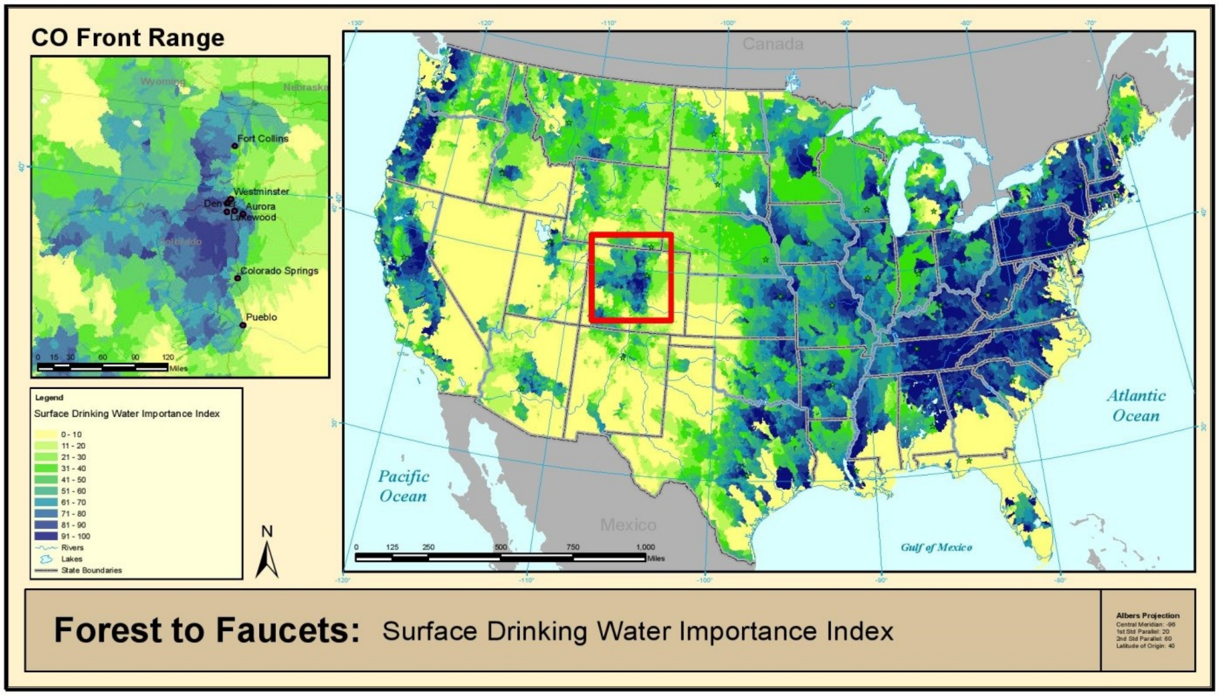

Figure 1 USDA forest service surface drinking water index showing forested areas that are critical to drinking water supply in Denver, CO. Source: http://www.fs.fed.us/ecosystemservices/pdf/forests2faucets/F2F_poster_IMPCO26.pdf

2.2.2 Managing watersheds to protect drinking water quality and reliability: A partnership between the Nature Conservancy and the City of Bethlehem, Pennsylvania

In 2010, the city of Bethlehem in Pennsylvania partnered with the Nature Conservancy, a non-profit conservation organization, to manage the city's 22,000-acre watershed in the southern Pocono Mountains (Mockrin et al. 2014). Bethlehem Water Authority, the city's water utility service provider, provides water for about 110,000 residents in 10 municipalities (The City of Bethlehem 2008; Mockrin et al. 2014). The partnership is estimated to last for about 60 years. Throughout these 60 years the city's source of drinking water will be protected as a "working" forest (Mockrin et al. 2014). The Nature Conservancy's Working Woodlands forest conservation program is aimed at protecting forests and improving forest managements (The Nature Conservancy 2011). Through this program, the Nature Conservancy will use a number of land rights coupled with forest management certification and carbon payments to protect the watersheds that are critical to the City of Bethlehem's water supply (The Nature Conservancy 2011; Mockrin et al. 2014). The partnership will therefore limit commercial development on the forest lands (Sadowski 2011; The Nature Conservancy 2011; Mockrin et al. 2014).

In addition to the increased protection of watersheds leading to improvements in water quality and reliability, the City of Bethlehem will also benefit from sustainable management of timber and additional revenue from carbon credits (Mockrin et al. 2014)

2.2.3 The Southern Rockies watershed project

After the 2003 Lost Creek forest fire in Alberta, the Southern Rockies Watershed Project (SRWP) was implemented to examine the impact of forest fires on watershed values (Silins et al. 2009). Specifically, the project was aimed at understanding the effects of the Lost Creek fire on the hydrology, water quality and aquatic ecology of the affected watersheds (Silins et al. 2009). The project is located at the highest drinking water producing area of the Rocky Mountains with a mean annual precipitation of between 800mm-1360mm (Silins et al. 2016).

In 2004 the project team established research watersheds to obtain data from the first post-forest fire hydrologic events (Silins at al. 2009). They instrumented seven watersheds to enable automated and manual hydrometric, water quality and stream ecological monitoring (Silins et al. 2009). Two of these watersheds; Star Creek and North York were used as reference points for the five burned watersheds. Figure 2 shows a map of the project with both the burned and unburned watershed used in the study. These watersheds range in size between 360-1315ha with an elevation of about 1800ha (Silins et al. 2009).

The hydrological and water quality data obtained from this project will be "linked with condition of downstream water resources at larger basin scales, including implications for municipal water supplies for drinking water" (http://srwp2.ales.ualberta).

One of the most important goals of the Southern Rockies Watershed Project is to know the mechanism by which water flows through forested watersheds and how threats to these watersheds will affect the flow of water (Southern Rockies Watershed Project n.d.). In the end the project can generate information important for the protection of watersheds that are critical to the supply of drinking water in Alberta (Southern Rockies Watershed Project n.d.).

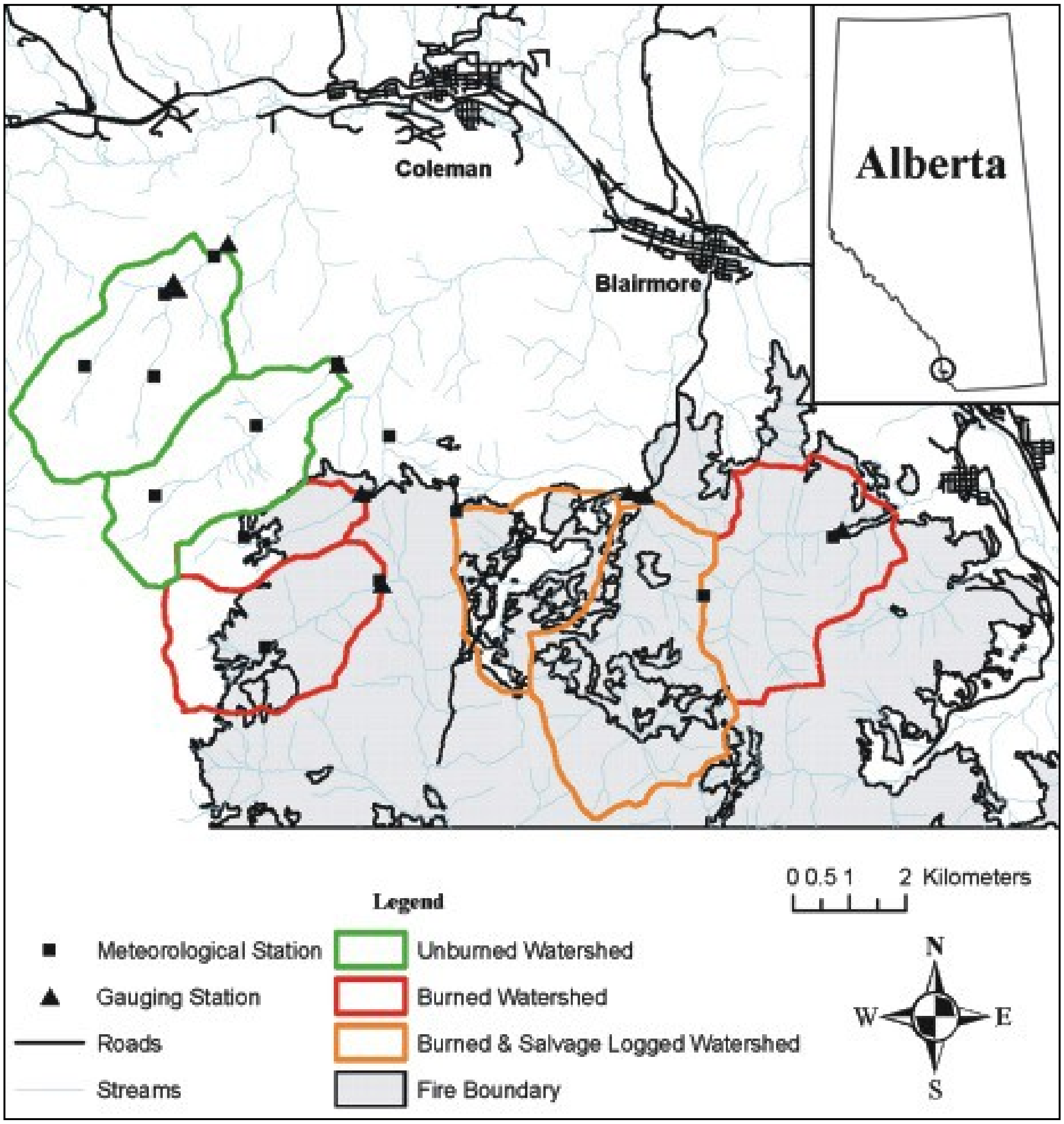

Figure 2 Southern Rockies Watershed Project map with the 2003 Lost Creek Forest fire boundary, meteorological stations, streamflow gauging stations and watersheds. Source: Silins et al. (2009).

The projects discussed above have largely examined the importance of forest management practices on drinking water reliability and not the economic aspects of these strategies. In order to assess the economic aspects, we need information on the benefits and costs of the various management strategies to increase drinking water reliability. An economic analysis of benefits and costs can help determine whether an investment in these management practices to improve drinking water reliability is an efficient decision.

2.3 Overview of stated preference methods

Benefit-cost analysis, as the name suggests, involves the comparison of the benefits and costs of any proposed activity in order to assess the economic efficiency of the activity. However, such analysis is impeded by the inability to place values on environmental goods and services that may be affected by this proposed activity (Carson 2000). Ideally the total economic value (TEV)[2] of environmental goods and services should be revealed by a set of institutional arrangements (Hanemann 1994; Grafton et al. 2004). This is not possible in a less ideal world. Various techniques have been developed to determine the economic value of these environmental goods. These techniques are broadly grouped into revealed and stated preferences methods.

Revealed preference methods obtain the value of nonmarket environmental goods based on observed behavior of individuals by linking purchases of marketed goods that are connected to the non-marketed environmental goods being valued (Grafton et al. 2004). For example, purchases of in-home water treatment equipment may indicate the demand for improved water reliability. However, in-home treatment may also be purchased to address taste, color or other aesthetic preferences. Stated preference methods, in contrast, determine the value of environmental goods either through voting or referenda where members of a community agree to increases in their taxes to provide the public good or service (Carson 2000; Grafton et al. 2004) or by asking questions about the choice of good or service in a multi-alternative setting (e.g. recreation sites). Respondents are basically asked to state their choice of or preference for certain environmental goods in a survey (Carson 2000). The most commonly used stated preference method is the contingent valuation method.

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[2] Total economic value is the sum of use and passive use or existence values (Carson 2000; Grafton et al. 2004).

2.3.1 The contingent valuation method

The contingent valuation (CV) method is a survey based method used to obtain the value of nonmarket environmental goods and services (Mitchell and Carson 1989; Carson 2000). It involves the elicitation of the tradeoffs individuals will make between a stated cost and increased quality and/or quantity of environmental goods that will improve their wellbeing. The stated cost may encompass increased taxes, higher prices associated with the provision of the good and user fees (Carson 2000). The value of the good elicited is therefore conditional on the existence of market for the good as described by the researcher (Grafton et al. 2004). In a simple contingent valuation survey, respondents are presented with an alternative policy that will improve conditions relative to the status quo of the environmental good. They are asked to make a choice between this alternative policy and the status quo. The distribution of the value of the good is elicited after randomly assigning costs of this policy to the respondents (Carson 2000).

The design of a CV survey follows a number of steps that will be outlined in detail in chapter four. The main valuation question follows various elicitation formats that comprises of referendum-style, open-ended, bidding game and payment card formats. In the open-ended preference elicitation format the respondents are asked to state their value for the good in a single question (Grafton et al. 2004). However Freeman (1993) argues that this preference elicitation format may present an unfamiliar task to the respondents. Preferences may also be elicited in a bidding game format or auctions. The referendum-style method is the most commonly used and accepted following the National Oceanic and Atmospheric Administration (NOAA) panel recommendations (Grafton et al. 2004).[3] The referendum-style elicitation format is used in the CV section of the study and the reasons are explored below.

Despite the success of the CV method in valuing environmental goods such as water resources in our application, there are a number of criticisms of the method. The

[3] This panel of experts was setup to assess CV as a valid damage assessment method following public criticism when it was employed as passive use loss assessment tool in the Exxon-Valdez oil spill case.

validity and reliability of results from CV studies have been criticized (Diamond and Hausman 1994; Hensher, Rose and Greene 2005). Validity, in this context, means that there is a relationship between the results obtained from CV studies and "real values". In other words, validity relates to the accuracy of the estimates from CV studies (Freeman 1993). There are different forms of validity. The first type relates to content validity which simply refers to the examination of the appropriateness of the survey instrument to elicit the economic value of an environmental good in the best way (Bateman et. al. 2002; Venkatachalam 2004). Another type of validity is criterion validity which simply means the comparability of survey values with an alternative measure. For instance if it is a private good that is being valued then its "real value" can be compared with the hypothetical value (Venkatachalam 2004). The final validity type is construct validity which is of two forms; convergent and theoretical validity. Convergent validity simply ensures the comparison of the results from stated and revealed preference methods (Bateman et al. 2002). Theoretical validity ensures that the preferences elicited conform to economic theory (Freeman 2003;Venkatachalam 2004).

On the other hand, reliability is defined as being able to obtain similar results from a given sample and a repeated sample (Loomis 1990; Hensher et al. 2005; Ozbafli 2009). In simple terms it is the "reproducibility" of the CV estimates (Venkatachalam 2004). The validity and reliability of estimates from CV studies have been attributed to certain design issues. Some of these design issues are as follows;

The first design issue surrounding the validity and reliability of CV estimates is the issue of strategic behavior (Grafton et al. 2004). There are some concerns that survey respondents behave strategically when responding to CV questions. For instance when individuals perceive that the actual payment obligation will not be on them, and the value that they report will influence policy, they will report a higher value leading to overestimation of the economic value (Grafton et al. 2004). On the other hand, if they perceive that it will be their responsibility to pay for the good, but that the amount stated may not influence provision of the good, then they will report lower values (Bateman et al. 1995; Grafton et al. 2004).

Another survey design issue, also related to strategic behavior, is hypothetical bias. This is the disparity between the real and hypothetical valuation of an environmental good (Loomis 2014). Because hypothetical market scenarios are presented to respondents in such surveys there are tendencies that the values they provide might not reflect the actual value of the environmental good. Studies that attempt to compare hypothetical and real values of goods show higher values for the former (Kealy, Montgomery and Dovidio 1990; Champ et al. 1997; List and Gallet 2001; Little and Berrens 2004; Champ, Moore and Bishop 2009; Loomis 2014). However, those two values tend to be consistent when the respondents are familiar with the good being valued (Grafton et al. 2004). CV studies must therefore make effort to address the issues of strategic behavior and hypothetical bias.

The next CV design issue often talked about in the literature is the issue of embedding effects (Kahneman and Knetsch 1992; Diamond and Hausman 1994; Bateman et al. 1995). A component of the embedding effect is the scope effect which occurs when changes in the amount of the environmental good being valued does not affect the value respondents place on it (Kahneman and Knetsch 1992; Grafton et al. 2004). CV studies reporting such results are referred to as scope insensitive and this insensitivity may be attributed to flaws in the survey design or implementation of the survey. Another component of the embedding effect is the order in which valuation questions are presented. CV practitioners have over the years found that the value placed on environmental goods in a sequence typically depends on the order in which the good is presented to the respondents (Tolley et al. 1986; Bateman and Langford 1997; Powe and Bateman 2003; Clark and Friesen 2008). Consequently, smaller quantities of environmental goods may get valued higher relative to larger quantities because they appeared first in the sequence of contingent valuation questions. Sequences of the goods being valued may also induce strategic behavior. For instance an individual may compare across goods presented in the valuation scenario to attempt to obtain the best deal from all those presented. This suggests randomization of question order be used to address this issue (Boyle, Welsh and Bishop 1993).

"Warm glow" is also a problem that surrounds CV studies (Andreoni 1990; Kahneman and Knetsch 1992; Grafton et al. 2004). This phenomenon occurs when respondents vote in favour of proposed actions because of general cause rather than specifics of the proposed action (Grafton et al. 2004). It appears that respondents are paying for “moral satisfaction” rather than a specific environmental good (Grafton et al. 2004). Asking follow up questions after valuation questions have been presented can help identify the presence of this phenomenon to a large extent (Grafton et al. 2004).

Another survey design issue relates to the preference elicitation format and the type of good being valued. Depending on whether the good being valued is public or private, the preference elicitation format may or may not exhibit incentive compatibility (Carson and Groves 2007). Incentive compatibility means that responding truthfully to a valuation question is the dominant strategy for the respondent (Cummings, Harrison and Rutström 1995; Carson and Groves 2007; Herriges et al. 2010). In the case of public goods if the preference elicitation format and payment vehicle are not binding, respondents are expected to always vote for the proposed action. For instance Carson, Groves and Machina (1999) showed that the single bounded preference elicitation format is not incentive compatible when a voluntary donation is used as the payment vehicle. In such a valuation scenario the optimal strategy for a respondent, who desires the particular public good being valued, is to agree to donate and then “free ride” when an actual fundraising is done (Carson, Flores and Meade 2001). These respondents do that in hopes that others will voluntarily donate for the provision of the public good (Carson, Flores and Meade 2001). This hypothetical preference is not reflective of the respondents’ “real” preferences (Carson and Groves 2007). The hypothetical value of the public good in this case will therefore be overestimated. Hence to elicit true preferences for public goods when using the single bound format the payment vehicle must be binding (Carson and Groves 2007).

In the case of the valuation of a new private good, the dominant strategy for a respondent interested in the provision of the good is usually to vote “yes”. The respondent knows that their vote of “yes” will increase the likelihood of the provision of the good (Carson and Groves 2007). They will however make the actual purchasing decision later and could change their decision (Carson et al. 2001; Carson and Groves 2007). The usage of the single-bounded preference format with a non-binding payment vehicle therefore overestimates the value of the private good.

In summary, all CV studies must be aware of these issues and make efforts to address them in the survey design. The CV section of this study was therefore designed following recommendations in the current literature on how to address these design issues in order to make the estimates of the value of drinking water reliability in Alberta valid and reliable.

2.4 Past studies on the valuation of drinking water reliability

Several authors have attempted to place values on drinking water reliability in both developed and developing countries. Below is a survey of some of these studies.

Howe et al. (1994) employed stated preference methods to determine the value of different levels of water reliability in three urban Colorado towns; Boulder, Aurora and Longmont. Using the referendum style elicitation format and different scenarios of water outages they found that 41-58% of the respondents in the three towns felt a decrease in water supply reliability is undesirable (Hensher et al. 2006). They however found that a large proportion of respondents in two towns were willing to consider lower levels of reliability although the baseline levels of reliability are already low. Those respondents were willing to accept between $4.53 and $13.99 per month for lower levels of water reliability. They also found that respondents who desired more reliable water supply were willing to pay between $4.53 and $5.99 per month for different levels of improved reliability.[4]

Barakat and Chamberlin (1994) used a stated preference method to estimate the value of water supply reliability in California. The survey was administered to residential customers within the service areas of ten California Urban Water Agencies (CUWA). They used the referendum style elicitation format to determine how much residents are willing to pay to avoid water shortages of randomly assigned magnitudes ranging from 10 to 50%, and frequencies from 3 to 30 years. They found that respondents were willing to pay more to avoid larger and more frequent water shortages. Respondents were willing to pay between $11.60 and $16.90 per month on their residential water bills to avoid water shortages.

Griffin and Mjelde (2000) used a stated preference method to value water supply reliability in seven cities in Texas. They used a combination of the referendum style and open ended elicitation formats to obtain respondents' WTP for hypothetical shocks to

[4] These values are measured in US dollars of the year of the studies.

their current and future water reliability. They estimated the distributions of these welfare measures using the logit and tobit models for the current and future shocks to reliability respectively.[5] The WTP to avoid current shocks to water reliability on average was between $25.34 and 34.39 depending on the duration and strength of the water shortfall. On the other hand the WTP for future reliability improvement was $8.47 per month.

Koss and Khawaja (2001) used a stated preference method to elicit California residents' preferences for different levels of water shortage improvements. They asked respondents for their WTP to avoid water outages of different frequency and severity. They found that respondents were willing to pay between $11.67 and $16.97 per month on their water bills to avoid water outages in the next 20 years.

Powe et al. (2004) elicited consumers in southeast England preferences for water supply options using stated preference methods. They found that given the current water supply reliability respondents were unwilling to pay for improvements in reliability. However in cases where future reliability is required, respondents were willing to pay to avoid negative environmental impacts. They validated these results using a "post-questionnaire focus group discussion approach".

Hensher et al. (2005) employed stated preference methods to measure households and businesses in Australia's capital city willingness to pay to avoid drought restrictions. They presented respondents with six choice sets covering restrictions on the use of water. Some of the attributes in the choice sets encompass the frequency of the drought restrictions, the expected duration of these droughts, and the level of drought restrictions. They found that respondents were not willing to pay for low level drought restrictions. Even though higher-level restrictions are not available every day, they found that the respondents are not willing to pay for such restrictions.

Hatton-MacDonald et al. (2005) used stated preference methods to estimate the implicit prices associated with different urban water supply attributes such as the frequency and duration of water supply interruptions in Australia. Survey respondents were asked to recollect their past experiences with water service interruptions and the level of inconvenience of these interruptions to their households using six choice sets.

[5] These models are described below.

They found that respondents are willing to pay between AUS$1.0 and AUS$1.5 per year for decreases in the duration of water service interruptions. They also found a WTP of between AUS$6.0 and AUS$6.3 per year for decreases in the frequency of water supply interruptions.

In the developing country context, Vásquez et al. (2009) used stated preference methods to assess households' willingness to pay for safe and reliable water in Mexico. The referendum style preference elicitation format was used and survey was administered through face-to-face interviews. They adopted a split sample approach in order to test for scope sensitivity. They found that households were willing to pay an additional charge of at least 45.64% of their current water bills for programs that will improve the safety and reliability of their water supply. The results of their scope sensitivity test indicate higher WTP for water quality and reliability than only water quality. Their study was therefore scope sensitive.

Gebreegziabher and Tadesse (2011) employed the stated preference method to determine households demand for reliable water supply in Northern Ethiopia. Using the referendum-style elicitation format, they elicited households' preferences for improved quantity, quality and reliability of water supplies. They also attempted to include the number of respondents who reported "zero" values for improved water services into their analysis. They found that households are willing to pay an additional amount of 16.2 cents per bucket of water for improved water services.

Saz-Salazar et al. (2015) used a stated preference method to measure WTP of consumers in Bolivia for improvements in their water supply. The found that 55% of the respondents were willing to pay some amount of money on their water bills for improved water supply. The mean WTP for the various districts surveyed ranged between 6 and 11 Bolivian pesos per month. As further analysis, they employed a two stage Heckman selection model to address the presence of large proportion of "zero" responses in the survey data.[6]

[6] "Zero" responses are discussed below.

2.5 Past studies on the valuation of electricity reliability

Water and electricity are essential and complementary utilities. It is therefore important to provide a review of some of the studies that attempted to value electricity supply reliability. A number of studies have valued electricity reliability in both developed and developing countries using stated and revealed preference methods. Carlsson and Martinsson (2008) used stated preference methods to estimate the WTP to avoid unplanned electricity outages in Sweden. They valued different characteristics of electricity outages like the duration, the time of the week of an outage and the time of the year. They sent out a mail survey to 1200 randomly selected individuals and 425 responses were valid for analysis. They found that the marginal WTP for electricity outage that occur during weekends in the winter is higher relative to the rest of the year. For instance the marginal WTP to avoid electricity outage in a 24-hour weekend is about $125 Swedish krona compared to about $105 Swedish krona for the rest of the year.

Pepermans (2011) used a stated preference approach to determine the value Flemish households place on continuous electricity supply. Data for the study were from a face-to- face interview conducted with about 1488 respondents. Survey respondents were asked about their experiences with electricity outages. It was found that on average households experienced 100 minutes of power outages per year. 25% of households experienced an annual power outage duration of about 23 minutes. Using parameter estimates from various econometric models, it was estimated that households are willing to pay €20.17 per year to avoid power outages in peak periods. They are also willing to pay €27.74 per year to have power outages in the summer rather than in the winter.

Amador, González and Ramos-Real (2013) used stated preference methods to analyze customers in Canary Islands willingness to pay for electricity service attributes including its reliability. Survey respondents were asked to choose between two hypothetical electricity service providers that differ in attributes in addition with their current supplier. Data for the study were gathered through a computer-aided personal interview. A total of 376 respondents each facing 9 choice scenarios provided valid responses for analysis. They found that respondents are willing to pay to avoid more frequent and longer power outages. For instance households are willing to pay €1.99 per month to reduce the number of unplanned electricity outages by 1 unit. They are also willing to pay €1.00 each month to reduce the duration of electricity outages by 5 minutes.

In the developing country context, Kateregga (2009) used stated preference methods to elicit power outage costs to consumers in 3 Ugandan suburbs; Kampala, Jinja and Entebbe. Survey respondents were presented with 8 different scenarios of water outages. The study adopted the payment card preference elicitation format. Using responses from 200 Ugandans, the study computed an estimate of between $0.66-0.72 to avoid an hour of power outage on a weekday morning. Similarly, the respondents were willing to pay 0.82 and 0.86 to avoid an hour of power outage on a weekday evening. Results of scope sensitivity tests indicate lower WTP for longer durations of power outages relative to shorter durations.

Abdullah and Mariel (2010) used a stated preference method to determine rural Kenyan households' willingness to pay to avoid announced power outages. Some key attributes in the choice sets included duration of the outage, the number of planned outages and the type of distributor. The survey was administered to 202 households each presented with 4 choice scenarios. They found that rural households are willing to pay between 51 and 61 Kenyan Shillings per month to avoid longer and more frequent power outages.

Twerefou (2014) used stated preference methods to determine households in Ghana willingness to pay to avoid unannounced power outages. Survey respondents were asked to recollect past duration and frequency of power outages. The study found that about 48.1% of the respondents claim to have experienced between 4 and 6 hours of power outages per day. Using parameter estimates from econometric models, the author computed a mean WTP of GHC 0.27 to avoid a kilo-watt-hour of power outage. Put into context, this estimate represents 1 and one half times the respondents' current electricity bills.

A few other studies valued electricity reliability using revealed preference methods. For instance, Maliszewski, Larson and Perrings (2013) used a revealed preference method to value the reliability of the electrical power infrastructure in Phoenix, Arizona. Specifically they measured the capitalized value of electricity reliability using a hedonic house price model. Their study was aimed at estimating the impact of the reliability of electricity reliability on the value of residential properties. This will help determine the marginal willingness to pay for electricity supply reliability. They measured electricity reliability challenges as accidental outages due to the failure of the electricity distribution system. They found that a 1% reduction in the number of unplanned electricity outages increased the value of residential properties by $704.

2.6 Chapter summary

This chapter has presented background information on drinking water reliability as well as techniques used by economists to value environmental resources such as drinking water. The chapter has presented initiatives by water utility service provided in Colorado, Pennsylvania and Alberta to limit threats to drinking water quality and reliability. A survey of past attempts to value drinking water reliability in different parts of the world has been presented as well. From the literature summarized above it is evident that attempts to value drinking water reliability have focused on when the changes in the water resources are relatively small. Also some studies employed preference elicitation formats that could lead to underestimation or overestimation of the welfare measures. The following chapter presents the theories behind the various econometric models used in this study.

CHAPTER THREE: THEORY AND METHODS

3.0 Introduction

In determining the economic value of drinking water reliability in Alberta, it is important to know the theoretical underpinnings of the econometric models used. This chapter presents the econometric modelling techniques for stated preference datasets and a description of the econometric models employed in the thesis. The chapter begins with a description of random utility models that are the building blocks of the econometric models. The chapter then presents different ways of computing welfare measures, a major goal of all stated preference methods. The chapter concludes with a review of some econometric problems that occur in modelling data from stated preference methods such as the presence of endogenous variables in the utility models.

3.1 Modelling data from stated preference methods

Generally the modelling of stated preference datasets of all kinds follows a common theoretical framework, the random utility model. The data obtained from the survey in this study are therefore analyzed following this framework which is outlined in detail below.

3.1.1 The random utility model (RUM)

The fundamental building block of almost all stated preference modelling techniques is random utility model where individuals are assumed to make utility maximizing choices based on some constraints (Haab and McConnell 2002). The concept was proposed by Thurstone in 1927 as a basis for explaining dominance judgements among pairs of offering (Adamowicz, Louviere and Swait 1998). Several authors have built on Thurstone's work (Lancaster 1966; McFadden 1974; Hanemann 1984; Haab and McConnell 2002).

A major assumption underlying the random utility model is that individuals know their utility with certainty whereas some components of this utility are unknown to the researcher (Haab and McConnell 2002; Grafton et al. 2004; Holmes, Adamowicz and Carlsson 2014). As an illustration, consider a discrete choice CV scenario where a decision maker, *i*, is faced with a decision to vote "yes" or "no" to a proposed management program. Assume that the only attribute of this program is its price.

Following Grafton et al. (2004), the decision maker's utility (*U*), composed of a systematic component (*V*) and a random component (ε), can be written as

$$U_{ij} = V_{ij} + \varepsilon_{ij} \qquad (1)$$

Where the subscript *j* indexes the two alternatives such that *j*=1 when the decision maker votes "yes" and = 0 when the decision maker votes "no". *V* is a function of observable components of the utility that includes income (*y*), price of the program, *p* and other sociodemographic characteristics (*Z*) of decision maker *i*.

Two possible scenarios exist in equation (1). If the decision maker chooses the proposed program, they receive it but their income is reduced by the price of the program. The indirect utility from this choice is represented as;[7]

$$V_{i1} = V_{i1}(Z_i, y_i - p) + \varepsilon_{i1} \qquad (2)$$

Where V_{i1} is the indirect utility this decision maker obtains from choosing the proposed program, y_i is the decision maker's discretionary income, Z_i represents other demographic characteristics of the individual and p is the cost of this alternative. ε_{i1} is the component of the utility known to the decision maker but unknown to the researcher.

However if they vote against the program, their income is not reduced and they will not receive this program. The indirect utility from this choice is represented as;

$$V_{i0} = V_{i0}(Z_i, y_i) + \varepsilon_{i0} \qquad (3)$$

Where y_i is the individual`s income and ε_{i0} is the random component of the utility from this alternative. Z_i represents other characteristics of the decision maker.

The random component of the utility function allows probability statements to be made about the choice of alternatives (Adamowicz, Louviere and Swait 1998; Grafton et al. 2004). The probability that the decision maker will vote in favour of the proposed program is the probability that the utility he obtains from the proposed program is greater than the utility from the status quo (Haab and McConnell 2002; Grafton et al. 2004). This probability statement can be written as;

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[7] The utility is indirect because it is obtained from income and not goods.

$$Pr(Yes) = Pr(V_{i1}(Z_i, y_i - p) + \varepsilon_{i1} > V_{i0}(Z_i, y_i) + \varepsilon_{i0}) \quad (4)$$

In order to understand why the decision maker will vote "yes", we must examine the utility difference between the two alternatives (Grafton et al. 2004). This utility difference will be a function of the cost of the program and the utility from the proposed program. The observable choice of "yes" is therefore modelled as a function of the utility difference in these two alternatives. Equation (4) can be rearranged as;

$$Pr(Yes) = Pr(\varepsilon_{i0} - \varepsilon_{i1} < V_{i1}(Z_i, y_i - p) - V_{i0}(Z_i, y_i)) \quad (5)$$

Two modelling decisions have to be made about equation (5). First, the functional form of the indirect utility function must be determined. Following Haab and McConnell (2002) if we assume a linear functional form for the indirect utility, the utility decision maker *i* obtains from each alternative can be written as;

$$V_{i1} = \alpha_1 Z_i + \beta_1(y_i - p) + \varepsilon_{i1} \quad (6)$$

$$V_{i0} = \alpha_0 Z_i + \beta_0(y_i) + \varepsilon_{i0} \quad (7)$$

Where α is a vector of parameters for each of the covariates (e.g. demographics) and a constant, β_1 is the marginal utility of money in the proposed alternative and β_o is the marginal utility of money in the status quo.

Equations (6) and (7) can be substituted into equation (5)

$$Pr(Yes) = Pr(\varepsilon_{i0} - \varepsilon_{i1} < \alpha_1 Z_i + \beta_1(y_i - p) + \varepsilon_{i1} - \alpha_0 Z_i + \beta_0(y_i) + \varepsilon_{i0}) \quad (8)$$

It is also assumed in the linear random utility model that the marginal utility of money between the status quo and the alternative program is constant (Haab and McConnell 2002). Further simplification and normalization by setting $\alpha_0 = 0$ to represent the status quo alternative yields[8]

$$Pr(Yes) = Pr(\varepsilon_{i0} - \varepsilon_{i1} < \alpha Z_i - \beta p) \quad (9)$$

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[8] Because of the assumption of constant marginal utility of money, the decision maker's discretionary income, y_i, cancels out after expanding equation (8).

However because the utility is assumed to consist of random and systematic components, the random components of the utility from the proposed program and status quo cannot be identified individually (Haab and McConnell 2002). A common random component, ε_i, can therefore be specified as the difference between both random components. The RUM now becomes

$$Pr(Yes) = Pr(\alpha Z_i - \beta p + \varepsilon_i) > 0 \quad (10)$$

The second modelling decision is to assume a specific distribution for the random component of the indirect utility function (Haab and McConnell 2002). The most commonly distributions used are the normal and logistic distributions. Following Grafton et al. (2004), the probability of voting "yes", if a normal distribution is assumed for the random component of the utility, is

$$Pr(Yes) = 1 - \Phi(-\alpha Z_i + \beta p) \quad (11)$$

Where Φ is the cumulative distribution function (CDF) of the normal distribution. This is the probit model. On the other hand assuming a logistic distribution for the random component yields the logit model. Both models are symmetric and hence facilitate estimation by software packages (Haab and McConnell 2002). The parameters α and β in (11) can be estimated using maximum likelihood estimation.

It is important to mention that the model in (11) can be expanded to include attributes of the proposed program. For instance attributes used in choice sets can be included in the model. The model will expand into;

$$Pr(Yes) = 1 - \Phi(-\alpha Z_i + \beta p + \Upsilon(q_1 - q_0)) \quad (12)$$

Where q_1 is a vector of attributes of the proposed management program and q_0 is a vector of attributes of the status quo. Υ is a vector of parameters that measure the effect of differences in attributes on the probability of a vote in favour of the proposed program.

As will be discussed in the empirical analysis below, in cases where multiple valuation questions are asked, the data take on a panel structure. It is therefore important to give an overview of panel data models with a special focus on binary outcomes in the next section.

3.1.2 Models for panel data with binary outcomes

Panel data give researchers flexibility in modelling heterogeneity in behavior of individuals (Greene 2003). The difference in models for dealing with panel data arises from whether the heterogeneity among individuals is observed or not. When the heterogeneity is observed for all individuals in the panel data, the data can be pooled and estimated using conventional models like logit and probit for binary outcomes. However, if the heterogeneity is unobserved then conventional models will produce inconsistent estimates (Wooldridge 2010). This is because the conventional models will omit these unobserved heterogeneities.

Panel data models are therefore broadly grouped into pooled and unobserved effects models (Wooldridge 2010). The pooled models assume constant intercepts for all observations (Greene 2003). The unobserved effects models assume that there is unobserved heterogeneity across individuals (Greene 2003). Depending on the assumption made about the correlation between this unobserved heterogeneity and the regressors in the model, unobserved effects models are grouped into fixed and random effects model (Wooldridge 2010). Fixed effects models assume that there is a correlation between the unobserved heterogeneity and other regressors in the model (Greene 2003; Wooldridge 2010). On the other hand random effects models assume no correlation between unobserved heterogeneity and the regressors in the model.

The random effects model has more "intuitive appeal" and allows the incorporation of respondents' specific demographic variables (Loomis 1997). The random effects model is therefore used in the study. Random effects can be introduced into (11) by assuming no correlation between the unobserved heterogeneity or individual effects and the determinants of utility. Introducing random effects into equation (11), following Greene (2012), yields

$$Pr(Yes) = 1 - \Phi(-\alpha Z_i + \beta p + \rho_i) \tag{13}$$

Where ρ_i is the unobserved heterogeneity/individual effects and it is assumed to be uncorrelated with Z and p. i indexes individuals in the sample. This model is called the random effects probit model and can be estimated by maximum likelihood.

3.1.3 The mixed logit model

In order to further explore the unobserved heterogeneities discussed above the mixed logit is used in this study. Also called the "random parameters logit model", the "random coefficient logit" or the "error components logit", the model is a generalization of the standard logit model allowing parameter estimates of each observed variable to be random for all respondents (Revelt and Train 1998; McFadden and Train 2000).

As an illustration of the mixed logit model following Revelt and Train (1998), consider a decision maker, i, faced with j alternatives in multiple choice situations indexed by t. The decision maker's utility from a choice can be written as

$$U_{ijt} = \beta'_i Z_{ijt} + \varepsilon_{ijt} \tag{14}$$

Where Z_{ijt} is a vector of variables observed by the analyst, coefficient vector β_i is unobserved for each decision maker and heterogeneous in the population with density $f(\beta_i \mid \theta^*)$ such that θ^* are the true parameters of this distribution. ε_{ijt} is also an unobserved and random component of the utility. Assuming that this random component is independently and identically distributed (IID) extreme value, the probability that decision maker i chooses alternative k, conditional on β_i in choice scenario t is standard logit (Revelt and Train 1998);

$$L_{ikt}\,(\beta_i) = \frac{e^{\beta'_i z_{ikt}}}{\sum_j e^{\beta'_i z_{ijt}}} \tag{15}$$

However the assumption of IID extreme value may be restrictive in real life because it does not allow unobserved variables that influence choices to be correlated across alternatives or choice scenarios (Hensher and Greene 2003). The mixed logit model relaxes this assumption. Integration of the conditional probability in (15) over all possible values of β_i yields the unconditional choice probability;

$$Q_{ikt}(\theta^*) = \int L_{ikt}\,(\beta_i) f(\beta_i|\theta^*) d\beta_i \tag{16}$$

The unconditional probability choice probability Q_{ikt} is a mixture of different logit distributions and conditional on the selected distribution of βi (Revelt and Train 1998). If a sequence of choices are used then the unconditional probability of the sequence of choices can be estimated (Revelt and Train 1998).

As Revelt and Train (1998) point out, maximum likelihood estimation of the unconditional choice probabilities in (16) is not analytically possible. The estimation is therefore performed using maximum simulated likelihood. The simulation is done by summing over random draws of βi from its distribution $f(\beta_i|\theta^*)$ (Revelt and Train 1998; Nahuelhual, Loureiro and Loomis 2004).

Again as pointed out by Revelt and Train (1998) and reiterated by Nahuelhual, Loureiro and Loomis (2004), the researcher's goal is to estimate θ, the population parameter which represents the mean and variance of the random variable that captures individual tastes or preferences in the sample. The random parameter can therefore be given different distributions such as the normal, the lognormal and the triangular distributions. The normal distribution allows some individuals to have positive parameters and others negative parameters (Train 1998). The lognormal distribution can be used in situations where the random parameters are expected to have only positive values.

Next we shift the discussion into computation of welfare measures after the models illustrated above have been estimated.

3.1.4 Computation of welfare measures

As discussed above the goal of employing SP methods is to provide values for nonmarket goods. The most common value measures obtained from stated preference methods are willingness to pay (WTP) and willingness to accept (WTA). WTA is an appropriate value measure when the individuals have ownership of the good being valued (Carson 2000). Otherwise WTP is the appropriate measure.

WTP is the maximum monetary amount that makes a decision maker indifferent between the status quo and the proposed improvement to the status quo (Haab and McConnell 2002). Assume that the change in environmental quality leads to a gain in utility, an expression for WTP can be written as;

$$V_{i1}(q_1, y_i - WTP) = V_{i0}(q_0, y_i) \tag{17}$$

Where V represents indirect utility from the alternatives, q_1 represents the new environmental quality, q_0 is the status quo and yi represents the decision maker's discretionary income. WTP is the amount of money that will make both sides of the equation equal.

Since the objective of the study is to measure the value of drinking water reliability, an environmental resource that is not owned by the respondents, WTP is the best measure of welfare and therefore used in the study. The attributes of the proposed management program to reduce the risk of water outages are varied across the sample to be able to calculate these welfare measures.

Following Haab and McConnell (2002), if a linear utility model that is additive in error is assumed, and the error is assumed to be normally or logistically distributed, the WTP for each attribute of the proposed management program, following equation (11), can be calculated as;[9]

$$E(WTP) = \frac{\alpha}{\beta} \tag{18}$$

[9] See Haab and McConnell (2002 pp. 33) for a complete discussion on the derivation of WTP from binary choice models.

Where α is a vector of estimated parameters on a vector of covariates Z and a constant, and β is the marginal utility of money (i.e. the estimated parameter on cost of the management program).

The WTP can also be calculated using a combination of covariates such as demographics. Equation (18) expands into

$$E(WTP) = \sum_{l=1}^{n} \frac{\alpha Z_l}{\beta} \quad (19)$$

Where Z is the mean of the covariates such as demographics and l represents one of n demographics included in the model. Note that since both α and Z are vectors of parameters and covariates respectively, $\alpha * Z$ is a vector multiplication. Note also that in situations where the covariates are dummies, one of the levels can be used and the WTP values can be interpreted as such.

The discussion presented above focused on modeling data from stated preference surveys using random utility models. An alternative approach for modeling such datasets is the random willingness to pay (WTP) or expenditure difference model (Cameron 1988; Haab and McConnell 2002). The underlying assumption of this approach is that WTP by itself is a "well-defined concept" (Haab and McConnell 2002, pp. 50). WTP is therefore expressed as a function of program attributes and a stochastic error term. In order to estimate this model, a specific functional form must be assumed for the relationship between WTP and attributes of a program. For instance WTP can be expressed as a linear function of attributes and the stochastic error term. WTP can also be expressed as an exponential function of a linear combination of attributes and the stochastic error term (Haab and McConnell 2002). Following Haab and McConnell (2002) the exponential WTP model is written as;

$$WTP_i = e^{\alpha Z_i + \varepsilon_i} \quad (20)$$

where i represents the decision maker and ε_i is the stochastic error component of the WTP function with a mean zero and an unknown variance σ^2.

The probability that the decision maker will respond "yes" to a valuation question, given the bid amount, is the probability that the random willingness to pay function is greater than the bid amount (Haab and McConnell 2002). This probability function can be estimated using maximum likelihood after distributional assumptions are made about the stochastic component of the WTP function. Descriptive statistics of WTP such as the mean can then be computed using parameter estimates of the model. Following Haab and McConnell (2002) when a normal distribution is assumed for the error term, the mean WTP can be computed as;

$$E(WTP) = e^{\alpha Z_i + \frac{1}{2}\sigma^2} \tag{21}$$

Where $\sigma = \frac{1}{\beta}$

It is important to mention that in the exponential random WTP model the expected value of WTP is dependent on the assumed distribution for the error term. Hence probit and logit models will not have the same WTP as in the case of the linear random utility model (Haab and McConnell 2002). The welfare measures are therefore contingent on distributional assumptions made about the error term.

3.2 Issues that arise in the econometric modelling of stated preference data

Just as in any econometric modelling approach, a number of issues arise when modelling stated preference datasets. Two of such issues arise in this study and are explored below.

The first issue relates to the presence of a proportion of respondents in the sample who vote “no” to the valuation question. Two types of “no” votes normally exist in valuation studies. Respondents may vote “no” to the valuation question because they are indifferent between the status quo of the good being valued and improvements to the status quo. For instance vegetarians may not care about improvements in meat quality and may report “zero” responses when asked to place values on it (Kristom 1997).[10] These are termed true “zeros” or “nos”. On the hand, some respondents may vote “no” to the valuation question although they expressed interest in the good being valued in other parts of the survey (Freeman 1986; Strazzera et al. 2003). Such respondents may vote “no” because they believe they are entitled to the good being valued and it is therefore “unethical” to ask them to pay for its provision (Freeman 1986). These responses are termed protest responses (or “zeros”) in the literature. It has been suggested that asking

[10] “Zero” is used in this context to reflect a vote of “no” to SP valuation question.

follow up questions after the valuation questions has been presented can help distinguish between true and protest responses (Strazzera et al. 2003).

The other econometric issue relates to the presence of endogenous variables in the utility function. So far the models discussed above assumed no correlation between the systematic and random components of the random utility function. What if this assumption breaks down? Endogeneity occurs when the random component of the indirect utility function is correlated with any of the variables that form the deterministic component of the utility function (Wooldridge 2010). Using standard parametric estimation under this circumstance will yield inconsistent results (Fernandez-Antolin, Stathopoulos and Bierlaire 2014). This is because the estimated effects of variables in the model will also capture the effects of unobserved variables that are correlated with them (Guevara-Cue 2010). Generally endogeneity can arise due to simultaneity bias, omitted variables or measurement error in the deterministic component of the utility function (Guevara-Cue 2010). Endogeneity due to simultaneity bias arises when an explanatory variable and the dependent variable are jointly determined (Guevara-Cue 2010). As the name suggests, endogeneity due to omitted variable bias occurs when a factor that determines the outcome variable is excluded from the model. This factor will therefore go into the error term making it correlated with the explanatory variables. Finally when there are measurement errors in a variable, those errors will be carried into the error term thereby creating a correlation between the error term and the measured variable (Fernandez-Antolin, Stathopoulos and Bierlaire 2014).

Suggested methods in the literature for dealing with both issues are explored in detail below.

3.2.1 Dealing with the presence of large proportion of “zero” responses in SP data

Several authors have developed models to address “indifference" to scenarios in stated preference valuation questions (McFadden 1994; An and Ayala 1996; Kristom 1997; Werner 1999). McFadden (1994) proposed a model that allows a point mass distribution at zero. An and Ayala (1996) proposed a “mixture model” to deal with large proportion of zero responses in stated preference data. Their model also allowed a point mass at zero and nested the conventional probit and logit models as a special case. Kristrom proposed the spike model to allow non-zero probability of zero WTP. The model assumes that some respondents out of a sample have no value for the good being valued and therefore have a zero WTP for it. Werner (1999) applied the spike model using a double-bounded CV elicitation format and also separated the respondents in the sample into two; those with zero WTP and those with a positive WTP that is lower than offered bid amount.

This study attempted to incorporate the proportion of respondents not in the market for water outage risk reductions because of a lack of perceived risk perceptions into the econometric model estimations. Kristrom’s simple spike model is adopted in the study and explored in detail below.

Kristrom’s simple spike basically divides respondents in a sample into two groups; those with zero willingness to pay (WTP) and those with positive WTP. Kristrom (1997) argues that respondents who answer “no” to a valuation question are composed of two groups; those who are out of the hypothetical market and those whose WTPs are lower than the offered bid amounts. In order to identify those who are out of the market, Kristrom proposed a new question format that asked those who voted “no” whether they will be prepared to pay anything at all (Kristrom 1997). In the current study however, the “spike” is clearly defined because the respondents with no water outage risk perceptions are out of the hypothetical market for a risk reduction of water outages. Implicitly, they have a zero WTP because of a lack of perceived risks to water reliability. Using Kristrom’s simple spike to model these data allows them to have a non-zero probability of zero WTP.

As an illustration, consider a respondent faced with a decision to accept or reject a hypothetical amount of water outage risk reduction (say from q^0 to q^1) for a given sum of money, C. Following Kristrom (1997) but changing notation, the WTP of this respondent for the change in risk can be written as

$$V_{i1}(q_1, y_i - WTP) = V_{i0}(q_0, y_i) \quad (22)$$

Where V(y, q) is the respondent's indirect utility with y being the income.

Consequently, the probability that the respondent's WTP does not exceed the amount C can be written as

$$Prob(WTP \leq C) = F_{wtp}(C) \quad (23)$$

Where F_{wtp} (C), the cumulative distribution function (CDF) of C, is a right, continuous, non-decreasing function.

Kristrom's simple spike model assumes the following distribution function for the WTP;

$$\begin{aligned} F_{wtp}(C) &= p \qquad if\ C = 0 \\ &= G_{wtp}(C) \quad if\ C > 0 \end{aligned} \quad (24)$$

where the probability of non-participation, p ∈ (0, 1) and the CDF of positive WTP, G_{wtp} (C), is a continuous and increasing function. It can be seen in (24) that the distribution of WTP is not continuous as there is a discontinuity (or spike) at zero.

Randomizing the values of C across the sample of respondents will produce an estimate of the value of the change from q^0 to q^1. In the case of water risk reduction valuation this will represent the value of the hypothetical water outage risk reduction.

The spike model uses two valuation questions. One question determines whether the respondent is a participant of the contingent market or not.[11] The other question is the main valuation question that asks whether the respondent will vote in favour of the proposed program at the given bid amount or not. It is therefore important to define

[11] Valuation tasks that ask this type of question do so after the main valuation question is presented.

indicators for participation and willingness to pay. In our study the variable “S” = 1 is created if respondents have positive water outage risk perception and 0 if they did not expect water outages[12]. Similarly, the variable “T” represents the respondents’ responses to the valuation question based on the offered bid amount. T=1 if the respondent is willing to pay the offered bid amount; 0 otherwise.

The log-likelihood function for the sample can then be written as;

$$L = \sum_{i}^{N} S_i\, T_i In\left[1 - F_{wtp}(C)\right] + S_i T_i (1 - S_i) \ln\left[F_{wtp}(C) - F_{wtp}(0)\right] + (1 - S)\ln[F_{wtp}(0)] \tag{25}$$

Essentially the log-likelihood function shows that the sample contains three groups of respondents; participants of the market willing to pay the offered bid amount, participants of the market not willing to pay the offered bid amount and non-participants of the market.

In order to estimate this likelihood function in (25) a specific functional form must be assumed for the distribution of WTP. Just as in Kristrom (1997), the logistic distribution is assumed. The distribution is defined as;

$$\begin{aligned} F_{wtp}(C) = \quad &= [1 + \exp(\alpha)]^{-1}\ if\ C = 0 \\ &= [1 + \exp(\alpha - \beta C)]^{-1}\ if\ C > 0 \end{aligned} \tag{26}$$

Where α is the marginal utility of water outage risk reduction and β is the marginal utility of money.

The distribution of the WTP in (26) is substituted into (25) and estimated using any standard statistical software. In this study the above log-likelihood function was programmed into NLOGIT 5.0 and estimated using maximum likelihood. Note that for

[12] Respondents who do not expect any water outages are assumed to be out of our defined market for water outage risk reduction.

comparison of results, different distributions for the WTP were assumed as well. The normal and log-normal distributions of WTP were assumed and the results are presented below.

According to Kristrom (1997) after the likelihood function in (25) has been estimated, descriptive statistics of the WTP such as the mean, when a linear utility model is assumed, can be calculated as;

$$\frac{\ln[1+\exp(\alpha\ )]^{13}}{\beta} \tag{27}$$

The spike is the probability that WTP =0 and is calculated as;

$$\frac{1}{[1+\exp(\alpha)]} \tag{28}$$

Stated preference studies normally include covariates in the model to test for internal consistency and theoretical validity of the model (An and Ayala 1996). In order to allow covariates in the model, α in (26) is replaced with α + Z'δ, where Z' is a vector of covariates and δ is a vector of parameters to be estimated.

3.2.2 Dealing with endogenous variables in the utility function

Approaches for dealing with the presence of endogenous variables in binary choice models include the control function approach (Heckman 1978), full or partial information maximum likelihood estimation (Train 2003) and "special" regressor method (Lewbel 2000). Baum et al (2012) and Lewbel et al. (2012) provide a complete review of the various methods available for treating endogeneity in choice models including the advantages and disadvantages of the various methods. The maximum likelihood estimation is more efficient if two joint distributions can be specified for the error terms in the outcome equation and the reduced form equation (Fernandez-Antolin et al. 2014). On the other hand the control function approach is more flexible. As will be discussed below

[13] This formula restricts WTP to the positive quadrant. The WTP is therefore weighted by the probability of participation in this application to obtain unconditional WTPs.

since the approach is two-step estimation it allows flexibility in the specification of the first stage equations.

This study employed the control function approach for dealing with endogeneity in choice models following Petrin and Train (2010) and Lloyd-Smith et al. (2014). As an illustration of this approach, following Petrin and Train (2010), consider decision maker *i* choosing between j alternatives. Assuming an additive error component for utility, the utility the decision maker obtains from alternative *j* can be written as;

$$V_{ij} = V\left(Z_{ij}, M_{ij}, \beta_i\right) + \varepsilon_{ij} \quad (29)$$

Where M_{ij} is the observed endogenous variable such that $cov(M_{ij}, \varepsilon_{ij}) \neq 0$ and β_i is a vector of parameters that represent tastes of decision maker *i*. Other terms have the same definitions as above.

The endogenous variable, M_{ij}, can be expressed as a function of all the exogenous variables in the utility function in (29), other variables that do not enter the utility function directly (instruments) and an additive random component, μ_{ij};

$$M_{ij} = (Z_{ij}, W_i) + \mu_{ij} \quad (30)$$

Equation (30) is called the reduced form equation, where Z_{ij} is a vector of exogenous covariates in the utility function, W_i is a vector of instruments, and μ_{ij} is the error term in this reduced form equation. Under the maintained assumptions of the control function approach, μ_{ij} and ε_{ij} are independent of Z_{ij} and W_i. The endogeneity problem arises because of the correlation between μ_{ij} and ε_{ij} (Petrin and Train 2010). This implies that M_{ij} *and* ε_{ij} are also correlated.

The control function approach involves defining a "control" variable that when conditioned on will remove endogeneity in the utility function and make standard estimation techniques produce consistent results (Imbens and Wooldridge 2007; Petrin and Train 2010; Fernandez-Antolin, Stathopoulos and Bierlaire 2014). If this can be successfully done then the additional variation in M_{ij} will be uncorrelated with ε_{ij} (Petrin and Train 2010). However in order to define this "control" variable note that the error term of the utility function in (29) can be decomposed into two parts as;

$$\varepsilon_{ij} = \lambda\mu_{ij} + \pi_{ij} \quad (31)$$

Where π_{ij} is the portion of the error term in the utility function that is uncorrelated with the endogenous variable and μ_{ij} is the "control" variable with parameter λ.

Equation (31) can be substituted into equation (29), where μ_{ij}, which is the error term in the reduced form equation, becomes an additional explanatory variable. However since we do not observe the error term in the reduced form equation, an estimate of it can be obtained because we observe the endogenous variable and the instruments. This estimate is obtained with sampling error (Imbens and Wooldridge 2007).

The control function approach is a two stage estimation process (Imbens and Wooldridge 2007; Petrin and Train 2010). The reduced form equation in (30) must first be estimated. The number of the reduced form equations depends on the number of endogenous variables in the utility function. The residuals from the reduced form are then used to calculate the control function variable which enters the indirect utility function as an additional explanatory variable (Petrin and Train 2010). It is worth noting that different functional forms of the control function can be specified.

However because the second stage estimation uses an estimate of the residuals instead of the true error term, the additional difference between the "true" reduced form error and the estimated error must be taken into account in the second stage estimation (Petrin and Train 2010). The standard errors of the utility model parameters must therefore be adjusted to account for the sampling error with which the control function is calculated (Imbens and Wooldridge 2007; Petrin and Train 2010). Popular methods for correcting the standard errors include the jackknife and bootstrap methods (Petrin and Train 2010).

As indicated above, we suspected that our water outage risk perception variables might be endogenous in our models such that unobserved factors that determine the choice of water reliability risk reducing programs might be correlated with risk perception variables. We employed the method discussed above and the results are presented below.

3.3 Chapter summary

This chapter has presented the theoretical justification of the econometric methods employed to value the reliability of drinking water in Alberta. This study uses a hybrid of stated preference methods and also uses different functional form specifications of welfare measures as robustness checks. The study assesses three types of water reliability, and the methods used to address reliability. The study also elicited absolute risk perceptions which are not done in many studies. As discussed above the study also attempts to correct the potential endogeneity of these absolute risk perceptions elicited in the survey. The study again adopts statistical models that incorporate respondents who are indifferent to water outage risk reductions in the analysis without compromising the analysis.

CHAPTER FOUR: SURVEY DESIGN AND IMPLEMENTATION

4.0 Introduction

Chapter 2 described the use of stated preference (SP) methods to assess the value of drinking water reliability in Alberta. The success of these methods however depends on the design of the instrument used in preference elicitation. This chapter presents an overview of the design of the survey instrument, and its implementation.[14] The steps followed in the design of the various components of the survey instrument are outlined. Specifically the chapter presents information on the focus groups and pilot surveys that helped to produce the final survey instrument. The chapter concludes with a discussion of the various components of the final survey administered to Albertans.

4.1 Survey development steps

As discussed above, most of the criticisms of stated preference methods relate to the reliability and validity of estimates. These criticisms maybe attributed to flaws in the design of the survey. Carson (2000) points out that the success of SP studies is contingent on the proper design of the survey instrument to be used. It was therefore important to follow recommendations in the literature on how to deal with SP survey design issues in order to obtain valid and reliable estimates of the value of drinking water reliability in Alberta.

4.1.1 Literature search

Prior to the development of the survey for eliciting Albertans' willingness to pay for water outage risk reductions, relevant literature was reviewed. Two broad groups of literature were reviewed. The science literature was reviewed to identify various ways of treating drinking water. This literature revealed forest and watershed management as a method of improving drinking water reliability in addition to traditional treatment

[14] It is important to mention that I was not involved in the survey design process as it was done before I became a part of the project team. This chapter is therefore an outline of the survey design and pilot phases as conducted by the survey team.

infrastructure (Dissmeyer 2000; Rieberger et al. 2010; Emelko et al. 2011). The economics literature was also reviewed to examine how various authors have analyzed water supply reliability using stated preference methods. As discussed above various authors have used one SP method or the other to measure the value of water reliability (Howe et al. 1994; Griffin and Mjelde 2000; Hensher, Shore and Train 2005).

After the literature search, the next steps in the development of the survey instrument consisted of constructing the initial survey instrument, testing it through focus groups and then pre-testing it through a pilot survey. The refined survey was then implemented. These steps are discussed in detail below.

4.1.2 Focus groups

After constructing the initial survey instrument it is important to refine it using focus groups. In general, focus groups are led by moderators and consist of a few respondents (Bateman et al. 2002). The recommended number of participants in focus groups ranges between 6 and 12. Having too many people in focus groups may prevent some participants from contributing effectively whereas having too few participants may create dominance of discussions by few individuals and may not provide sufficient diversity in perspectives (Bateman et al. 2002).

Conducting focus group as part of the survey instrument development process is important for a number of reasons. First, focus groups help the researcher to gauge how well the typical respondent would answer the questions. Second, the focus group participants help determine the potentially uncomprehensive and burdensome components of the draft survey instrument (Grafton et al. 2004). It is very difficult to communicate technical terms in a way that is understood by an audience with diverse backgrounds hence the need to use focus groups (Carson 2000). Third, focus groups also help identify concerns about the duration of the surveys. If participants raise concerns that the survey is too long and they become fatigued then there is the need to reduce the number of questions.

In designing the survey for assessing the value of drinking water reliability in Alberta, three focus groups were held in Edmonton, Calgary and Okotoks in the spring of 2014. Edmonton and Calgary represented the urban sector of Alberta whereas Okotoks represented the rural sector. These focus group discussions consisted of 8-12 people. These three focus groups helped to address wording and communication problems in the survey as well as other survey design issues. They also helped inform the initial bid design for the valuation questions. It was suggested at these focus group discussions that some questions asked in the initial draft of the instrument should be modified. For instance questions relating to threats of reliability of water services to respondents were modified. Also, the initial survey instrument wanted to elicit information on electricity service outages as potential instruments for treating endogeneity of the numerical water risk perception variables as discussed below. However the focus groups suggested replacing this with internet service outages as communities that experience water outages may also experience internet outages.

The survey instrument was updated to reflect the suggestions received at the three focus groups. This was important in order to obtain the needed information to produce valid and reliable estimates of the value of drinking water reliability in Alberta.

4.1.3 Pilot survey

The next survey design step after focus groups is to test the instrument through a pilot study. Bateman et al. (2002) recommended that pilot studies should constitute between 25 and 100 respondents depending on the total number of respondents expected for the full survey. They also recommend the maintenance of randomness in the sample selection for pilot studies.

Pilot studies help to examine how well the survey design instrument works (Carson 2000). They also help in testing the bid amounts selected for the proposed management program. The literature search may reveal some bid ranges that the pilot studies can help validate. The responsiveness of survey participants to selected bid ranges after data from pilot studies have been analyzed gives an indication of appropriate levels to use in the bid design. The number of pilot studies basically depends on the extent to which the instrument performs well after each pilot.

In this application, once the survey instrument was updated to reflect comments and suggestions received at the focus groups, one pilot study was done. The pilot survey was administered online to 155 respondents between January and February, 2015. Just as recommended, randomness was maintained in the sample selection for the pilot.

The results of the pilot survey were analyzed. The pilot survey results indicated that on average respondents took 30 minutes to complete the survey. This was in conformity with the length of survey presented to the respondents at the beginning of the instrument. It again indicated that about 78% of the respondents used for the pilot study lived in urban areas. Results from the econometric analysis of pilot survey data indicated that respondents tend to vote for the proposed program presented in the contingent valuation scenario at lower bid amounts as one would expect. The results from the hybrid valuation question were however mixed. Votes for the proposed program were insensitive to the bid amounts. These could be due to improper randomization of the bid amounts. The randomization was therefore modified in the final survey administration.

4.2 Survey administration

Important issues about survey administration include the selection of relevant population, mode of survey administration, sampling approach and the sample size (Hoyos and Mariel 2010). Because the survey aimed at eliciting trade-offs Albertans would be willing to make between reduced risks of drinking water reliability and money, the population of interest was Albertans.

In terms of administration of SP surveys, they are generally administered in three common modes; mail, face-to-face and internet. Mail surveys are relatively inexpensive and make it easier for respondents to answer sensitive questions. They also allow the application of a random sampling approach using postal addresses. However they have low response rates and tend to be time-consuming (Bateman et al. 2002). They also tend to encounter sample selection bias because people interested in the issue being evaluated are more likely to return the surveys (Carson 2000).

Face-to-face interviews on the other hand have high response rates and are useful when the survey instrument involve complex tasks (Hoyos and Mariel 2010). They also allow the researcher to probe further for clarifications on some unclear responses. These advantages come at a cost in the form of interviewer bias such as “social desirability bias” where the respondent answer questions in a way to please the interviewer (Champ and

Welsh 2006). The presence of third parties during face-to-face interviews could also influence the quality of data obtained using this mode (Champ and Welsh 2006). Face-to-face interviews are also relatively expensive to use because of remuneration for enumerators and other expenses.

Finally, internet based surveys facilitate quicker analysis after the survey is administered because there is normally no need for data entry. They also allow the usage of complex interview tasks (Bateman et al. 2002). However some respondents may reject the technology. For example older people may reject computer assisted survey administration modes. Also, unlike mail and face-to-face interviews that allow easy application of a random sampling approach, internet based surveys normally preclude random sampling and use opt-in panels (Bateman et al. 2002). Internet based survey also tend to use quotas on observable characteristics to approximate responses for a population.

In our application we adopted the internet mode of survey administration. We contracted Advanis, an Edmonton based survey research firm, to administer the survey online. The firm recruited participants from existing internet panel of potential respondents. We requested that the survey firm oversample respondents from rural communities in Alberta. The reason behind this is that rural communities tend to experience more water reliability challenges. This will also facilitate the comparison of water reliability challenges across different geographic locations in Alberta.

The survey research firm converted the survey into an online format and emailed it to the respondents. Out of the total number of respondents that received the survey, 2105 participated in it.[15] 855 of them started but did not complete the survey. The total number of surveys completed and valid for analysis was 1250.

We now shift the discussion to the specific components of the final survey.

[15] Unfortunately the survey research firm did not disclose the total number of people it sent the survey to. We are therefore unable to report response rates relative to the total number of invitations.

4.3 Components of the final survey

Carson (2000) provides a checklist for assessing a good SP survey. He recommends that every good SP survey should have seven sections. The first section is an introduction that is aimed at setting a general context for the decision to be made. Section two presents a detailed description of the good to be offered to the respondent. The third section establishes the institutional setting in which the good will be provided. The payment vehicle for the cost of the good is presented in section four. Section five then presents the method for preference elicitation. Debriefing questions aimed at understanding the preferences are asked in the sixth section. The final section asks sociodemographic questions about the respondents.

The survey used to assess Albertans' willingness to pay for water outage risk reductions broadly consisted of three major sections; the introductory section, the main valuation questions section and the demographic question sections. The three major sections had sub-sections that are consistent with the recommendation by Carson (2000). The introductory section comprised of warm up and water quality and reliability knowledge assessment questions. The section also had questions about experiences with and risk perception of water reliability challenges. The main valuation question section begins with a description of the status quo of water reliability in Alberta, a description of the proposed management program, a "cheap talk" script, and the valuation questions. The section also had some follow up question aimed at understanding the reasons behind respondents' preferences. The final section had questions aimed at collecting demographic information of the respondents. The design of each section of the survey is explored in detail below.

4.3.1 Introductory questions section

The set of questions presented in this section helps to set a general context for decision regarding water reliability as discussed above (Carson 2000; Grafton et al. 2004). As the name implies the questions presented here help respondents to think about their immediate environment. Questions regarding their length of stay in the current community, size of current and past communities, opinions regarding environment and development goals, and important areas of investment of public funds were presented in this section. The questions also focused on the source of water of their households and whether they pay water bills or not. This information was necessary to determine the payment vehicle for the valuation tasks.

The next sets of questions were aimed assessing respondents' knowledge level of their source of drinking water. Specifically the questions were aimed at assessing respondents' knowledge levels regarding water quality and reliability. Because we wanted to use the respondents' experiences and perceptions of water outages, it was necessary to define the kind of outages in this section. These are key components of the survey as they elicit the base case of water reliability. The section also asked questions about the respondents' experiences with "foreign" items such as sediments, pollutants and other contaminants in their regular drinking water source.

The questions were then focused on health concerns with water reliability. The section asked questions about the respondents' personal opinions regarding health concerns related to their water source. The section asked the respondents to compare the health effects of drinking water from their current source and another source (i.e. bottled water). Questions regarding past health issues attributable to their source of drinking water in the entire household were asked. Again in terms of water quality, the respondents were asked about their level of awareness with respect to certain types of microbes that can be found in tap water. In part these questions were asked because similar questions have been asked on similar surveys for many years. This provides a way to compare responses over time and different groups of people.

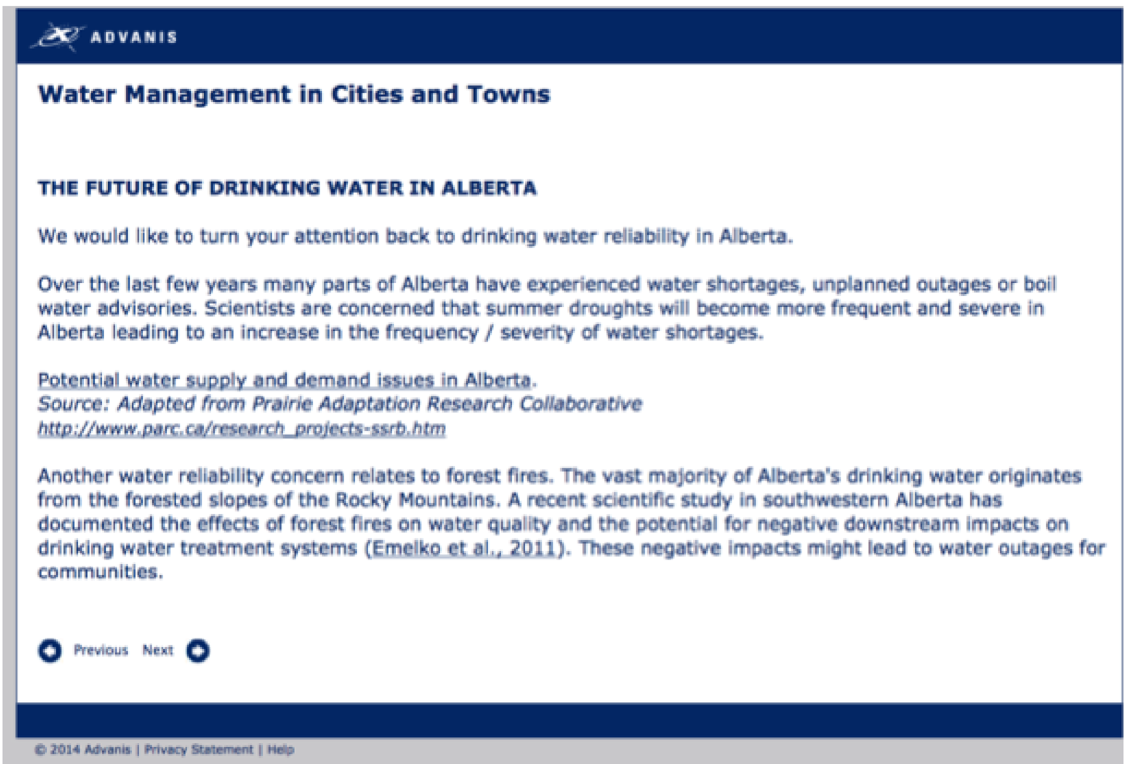
The section then elicited respondents' numerical risk perceptions of the three types of water outages discussed above. This was used to construct the hypothetical risk reduction levels for their preference elicitation. Questions about defensive expenditures with water outages such as the cost of a backup source of water were also presented in the introductory section.

The introductory section also contained questions about the respondents' risk perception of internet service outages. The rationale behind this is to use these perceptions as instruments to correct the potential endogeneity of the water outage risk measures elicited following Lloyd- Smith et al. (2014).

The survey then turned to the main valuation questions.

4.3.2 Main valuation scenario section

The section began with a description of the current state of water reliability in Alberta. A history of water reliability challenges in Alberta as well as the causes of water outages was presented in this section. The section also had background information on water reliability issues in other North American cities like Denver and how they addressed this issue. All these were done to familiarize respondents with the resource being valued. Below is an example of such descriptions. Also the full survey is presented in Appendix A.


ADVANIS

Water Management in Cities and Towns

THE FUTURE OF DRINKING WATER IN ALBERTA

We would like to turn your attention back to drinking water reliability in Alberta.

Over the last few years many parts of Alberta have experienced water shortages, unplanned outages or boil water advisories. Scientists are concerned that summer droughts will become more frequent and severe in Alberta leading to an increase in the frequency / severity of water shortages.

Potential water supply and demand issues in Alberta.
Source: Adapted from Prairie Adaptation Research Collaborative
http://www.parc.ca/research_projects-ssrb.htm

Another water reliability concern relates to forest fires. The vast majority of Alberta's drinking water originates from the forested slopes of the Rocky Mountains. A recent scientific study in southwestern Alberta has documented the effects of forest fires on water quality and the potential for negative downstream impacts on drinking water treatment systems (Emelko et al., 2011). These negative impacts might lead to water outages for communities.

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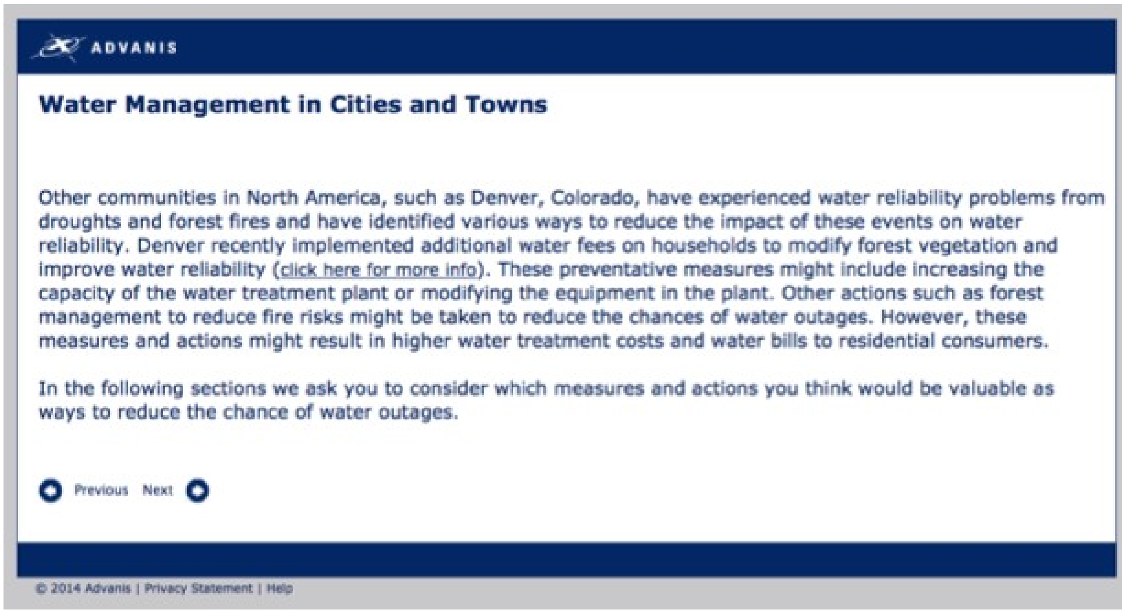
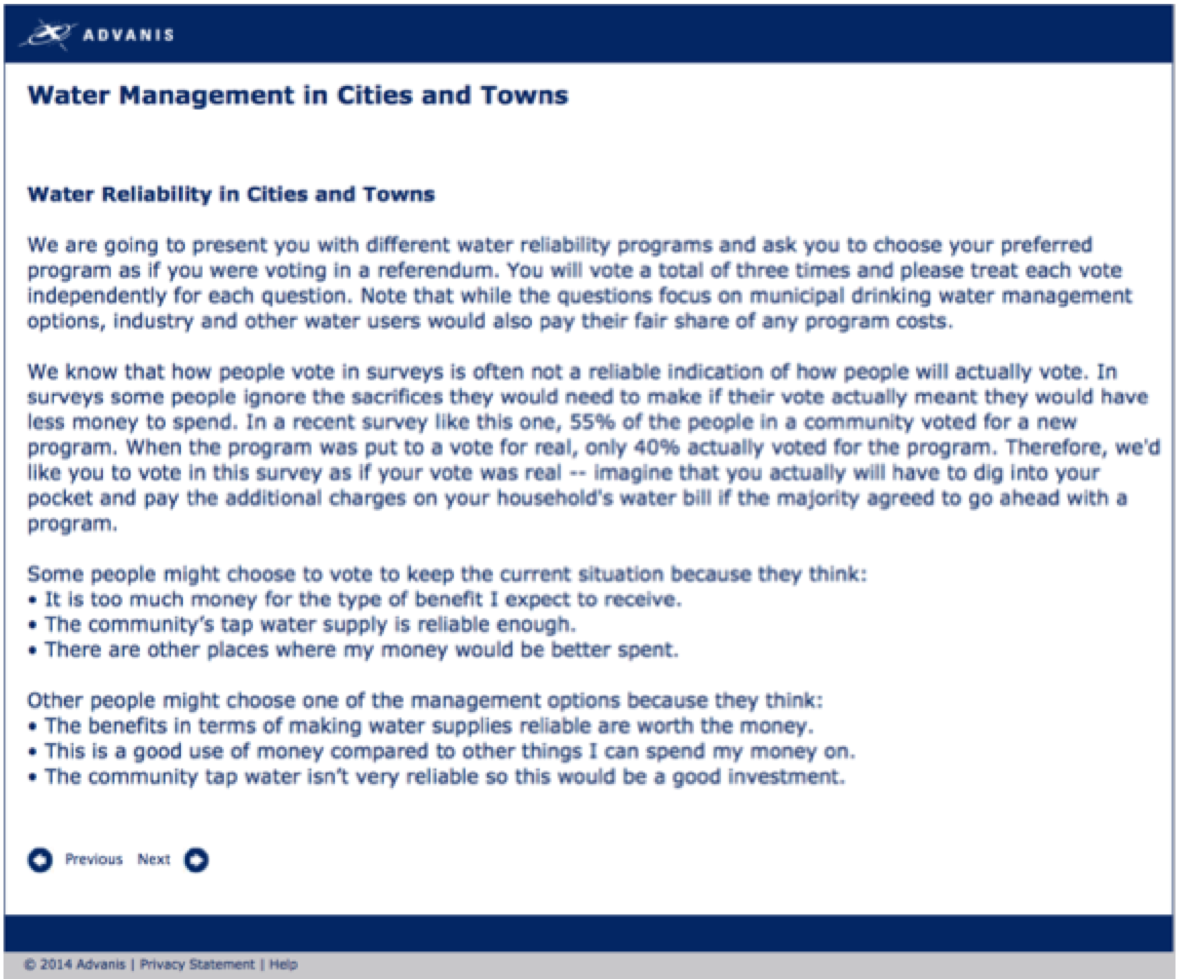


Figure 3 Description of the status quo and the good being valued

"Cheap talk" scripts have been used in the past as a way of minimizing hypothetical bias (Cummings and Taylor 1999; List 2001; Carlsson, Frykblom and Lagerkvist 2005). As a description, cheap talk scripts tell the respondents about the hypothetical nature of the survey but then urges them to treat it as an actual market transaction (Grafton et al. 2004). However there are cheap talk scripts that also try to reduce WTP by telling respondents that they typically provide high bid amounts. In our application, we wanted to remind the respondents that there are other substitutes for the good we are valuing, such as bottled or filtered water. We also wanted them to take the valuation task seriously, but we did not want to directly influence the value they place on the good. Therefore prior to the presentation of the valuation questions, the following cheap talk script was presented to the respondents.



ADVANIS

Water Management in Cities and Towns

Water Reliability in Cities and Towns

We are going to present you with different water reliability programs and ask you to choose your preferred program as if you were voting in a referendum. You will vote a total of three times and please treat each vote independently for each question. Note that while the questions focus on municipal drinking water management options, industry and other water users would also pay their fair share of any program costs.

We know that how people vote in surveys is often not a reliable indication of how people will actually vote. In surveys some people ignore the sacrifices they would need to make if their vote actually meant they would have less money to spend. In a recent survey like this one, 55% of the people in a community voted for a new program. When the program was put to a vote for real, only 40% actually voted for the program. Therefore, we'd like you to vote in this survey as if your vote was real -- imagine that you actually will have to dig into your pocket and pay the additional charges on your household's water bill if the majority agreed to go ahead with a program.

Some people might choose to vote to keep the current situation because they think:
• It is too much money for the type of benefit I expect to receive.
• The community's tap water supply is reliable enough.
• There are other places where my money would be better spent.

Other people might choose one of the management options because they think:
• The benefits in terms of making water supplies reliable are worth the money.
• This is a good use of money compared to other things I can spend my money on.
• The community tap water isn't very reliable so this would be a good investment.

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Figure 4 Cheap talk script

Two valuation questions were presented to the respondents; a CV scenario and a hybrid valuation question.[16]As discussed in chapter two, sequencing effects can arise in surveys. The sequence of the various valuation questions was therefore randomized to be able to test for order effects in the responses to the valuation questions. This will help examine whether the values Alberta place on different reliability programs in a sequence are affected by the order in which they receive the valuation tasks.

The two valuation questions are explored in detail below.

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[16] Three valuation questions were presented in this survey. However, the final valuation question, dealing with boil water advisories across the province, is beyond the scope of this thesis and it is therefore not discussed.

4.3.2.1 The contingent valuation scenario

Three different types of drinking water outage numerical risk perceptions were obtained from the introductory section of the survey. These are; short term water outages, longer-term outages, and boil water advisory perceptions. The contingent valuation question was constructed to obtain the trade-offs these respondent will make between reduction in their short term risk perceptions by a stated percentage and a stated cost. This valuation question was presented to only the respondents with positive short term risk perceptions.

The binary referendum style preference elicitation format was employed because it has incentive compatibility advantages (Champ et al. 2002; Carson and Groves 2007) . The respondents were therefore faced with two alternatives; their current risk perception level at no cost and a reduction in their risk perception by a specified percentage at a cost. Four levels of costs were selected; $10, $50, $125 and $250 following the pilot study outlined above. Because this was the valuation of a public good using a single bound elicitation format, a binding payment vehicle was needed. These will help make the hypothetical preferences reflect “actual” preferences (Carson and Groves 2007). The payment vehicle selected for this valuation scenario was an increase in the respondents’ water bills per year for the next 10 years. This payment vehicle is coercive as it will be an integral part of the respondents’ water bills

In order to test for scope effects in the valuation scenario, a split sampling approach with different level of risk perception reduction was adopted. Half the sample (with positive risk perceptions) received 50% reduction in risk while the other half received a risk reduction of 99%. We test for the sensitivity of the valuation task to scope in Chapter 6.

An example of this valuation question is presented below;

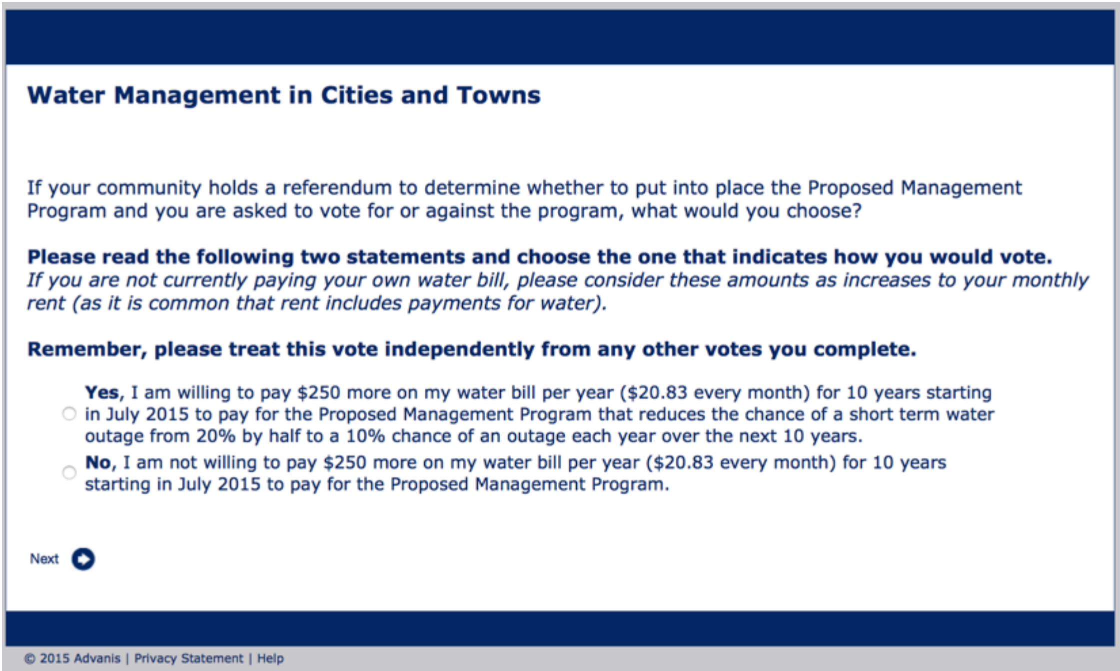


Figure 5 An example of the contingent valuation question

4.3.2.2 The "hybrid" valuation scenario

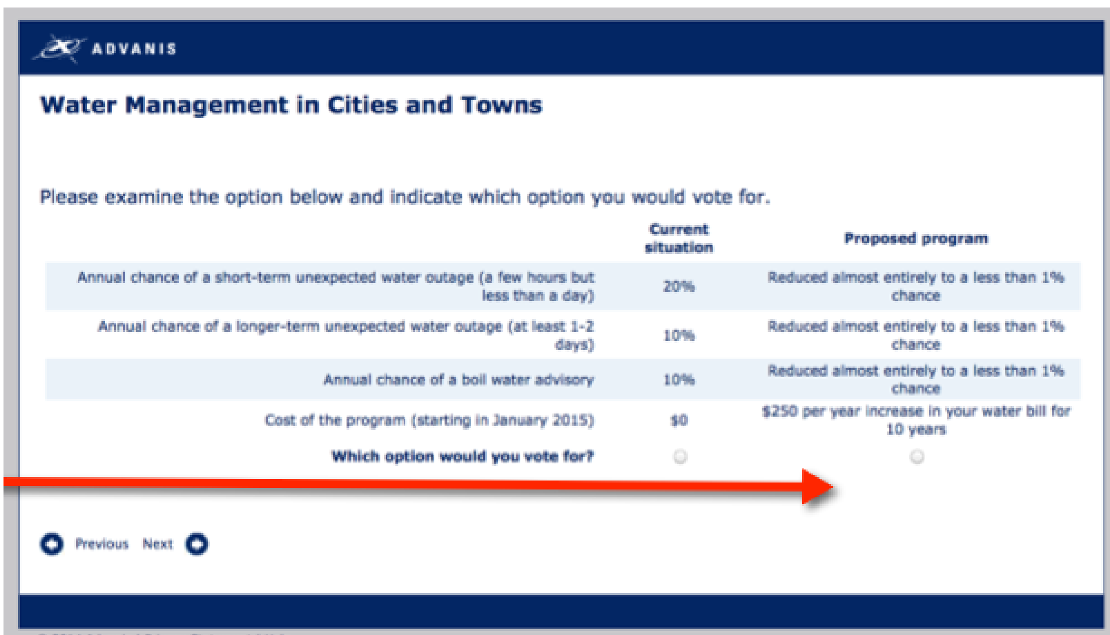
The hybrid valuation question was designed to contain more attributes of the proposed management program to improve water reliability.[17] This was particularly important in order to gauge respondents' preferences for different attributes of water reliability improving programs. This will help inform specific policy decisions regarding these attributes (Holmes, Adamowicz and Carlsson 2014).

This valuation question was presented to respondents with a positive risk perception of any of the three types of water outage. The payment vehicle and levels of exogenous risk reduction are the same as in the CV question. Again to test for scope effects the sample was split into two and presented with the two levels of exogenous risk reduction outlined above.

[17] Throughout this thesis the CV with more program attributes valuation question will simply be referred to as "the hybrid valuation question".

The valuation scenario contained a method by which the proposed program to reduce risk of water reliability problems will be carried out. The first reliability improvement method was investments to upgrade their communities' drinking water treatment system. This method specifically includes upgrading and replacing water pipes connecting water treatment systems to their households, investing in more modern water treatment system and creating more interconnections between water treatment systems. The other method of reliability improvement was forest and watershed management. This includes placing buffer strips along streams to reduce the amount of sediments and debris entering the water, reducing the amount of hazardous fuels in watershed to moderate the risk of forest fires and preparedness plans for incidence of forest fires.

Below is an example of this hybrid valuation question



ADVANIS

Water Management in Cities and Towns

Please examine the option below and indicate which option you would vote for.

	Current situation	Proposed program
Annual chance of a short-term unexpected water outage (a few hours but less than a day)	20%	Reduced almost entirely to a less than 1% chance
Annual chance of a longer-term unexpected water outage (at least 1-2 days)	10%	Reduced almost entirely to a less than 1% chance
Annual chance of a boil water advisory	10%	Reduced almost entirely to a less than 1% chance
Cost of the program (starting in January 2015)	$0	$250 per year increase in your water bill for 10 years
Which option would you vote for?	○	○

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Figure 6 An example of the hybrid valuation question

4.4 Debriefing questions

Debriefing questions help understand the reasons for responses that survey participants give to valuation scenarios. They help ascertain the reliability of these responses by identifying if there are differences between the scenarios presented and respondents' understanding of the scenario (Hoyos and Mariel 2010).

4.4.1 Certainty questions

Presenting certainty questions after valuation questions have been presented has been suggested as a way of reducing hypothetical bias in SP responses (Blumenschein et al. 1998; Blumenschein et al. 2008). When respondents are uncertain about how they will actually vote and still vote in favour of the hypothetical referendum, they may vote against it in an actual vote (Grafton et al. 2004). A certainty criterion can therefore be used to change these responses as will be seen in Chapter 6. This helps to elicit values reflective of "true" values.

In this application, a level of certainty question was presented after each valuation question to help make the estimates of water reliability valid and reliable. The certainty scale used in the survey ranged from 1 to 5 in increasing order of certainty. Below is an example of the certainty scale used in the survey;

On a scale from 1 to 5, where 1 is uncertain and 5 is certain, how certain are you that this is the option you would choose if this was an actual vote. Please select one response only.

Uncertain		*Somewhat Certain*		*Certain*
1	*2*	*3*	*4*	*5*

Figure 7 An example of the certainty scale

4.4.2 Consequentiality questions

As discussed above responses to SP valuation questions are sensitive to the individuals' belief that these responses have impacts on policy (Carson and Groves 2007; Herriges et al. 2010). These could help identify those respondents who feel that the survey is consequential and thus are less likely to behave strategically. It is expected that there will be a difference between values provided by respondents who believe that the survey is consequential and those who do not.

In this application consequentiality questions were presented. Respondents were given a rating scale ranging from 1 to 5 of the extent in which they believe their voting responses will inform policy. 1 represented “not taken into account” and 5 represented “definitely taken into account”. It is however important to mention that the test of the impact of these consequentiality questions of the value of drinking water reliability in Alberta is beyond the scope of this thesis.

4.4.3 Inferred valuation question

Respondents may overstate their willingness to pay in stated preference surveys to “look good” in the eyes of the researcher (Norwood and Lusk 2011). They however will not have the incentive to do same when asked about how others will respond to same questions.

Information on how respondents expect other community members and Albertans in general to vote was collected for the purpose of examining inferred valuation. This will reduce the so called “social desirability bias” where respondents answer questions in ways viewed favourably by others (Norwood and Lusk 2011). Inferred valuation questions were asked after each of the three valuation questions. An example of such questions, also not used in this study, is presented in the appendix.

4.5 Demographic information questions

Carson (2000) recommends asking questions aimed at obtaining demographic information about the respondents at the end of the survey. The demographic questions are important for a number of reasons. One, the information helps to compare responses to valuation question for different respondents across the sample. Two, the information can also help compare survey results with the Canadian census for Alberta to examine the representativeness of the sample. Three, the demographics can also be included in the utility model outlined above to examine preference heterogeneity. This will help examine the impacts of demographic information on the respondents’ utility from the choices.

Inclusion of demographic can also facilitate the test of internal consistency in the utility model.

In this survey the demographic information questions were simple and straightforward. Questions relating to gender, age, income, and educational level of respondents were asked in this section. The section also asked about respondents' membership of watershed management organization, their political affiliations and their residential status.

4.6 Chapter summary

This chapter has presented an overview of the development of the survey used to elicit the value Albertans place on the reliability of their drinking water. A preliminary survey was constructed and tested with respondents who participated in three focus groups in different parts of Alberta. The survey was modified after the focus groups and pretested through a pilot study. The final survey was administered on the internet by a survey research firm.

The chapter has also outlined the various questions presented to the respondents in the survey. The questions relate to their experiences with and risk perceptions of different types of water outages. The valuation questions elicited the trade-offs the respondents will make between reduced water outage risk perceptions and increased water bills. The survey then elicited sociodemographic information of the respondents. Some of this information was included in econometric model specifications and the results are shown in Chapter 6.

CHAPTER FIVE: SURVEY DATA DESCRIPTION

5.0 Introduction

This chapter presents a summary of the data obtained using the survey instrument described in chapter four. The chapter begins with a description of the demographic information of the survey respondents. The sample demographic information is then compared with the 2011 Canadian census results for Alberta to examine sample representativeness in terms of observable characteristics. The chapter then presents summary statistics of respondents' experiences with three different types of water outage events in the last 10 years, and their numerical risk perceptions of water outages in the next 10 years. In addition, the chapter also presents a comparison of these experiences and risk perceptions in rural and urban communities of Alberta.

5.1 Sociodemographic information of survey respondents

The demographic information collected in the last section of the survey is used to construct a demographic profile for the survey respondents. Table 1 presents the basic demographic information about the survey respondents. The average age of respondents in the survey is about 50 years. Most of the respondents in the survey fall between the ages of 31 and 70 years. The gender distribution in the sample is relatively equal. The average educational level of respondents in the sample is college education. About 44% of the respondents have completed university education. The median household income is about $125,000 per year although it is important to state that about 11% of the respondents in the sample did not declare their annual household income.

Table 1 also shows that most of the respondents own their places of residence. About 83% of the respondents pay water bills which lends support to the use of increases in water bills as payment vehicle in the preference elicitation questions. With regards to defensive expenditures on water, about 57% of the respondents in the sample claim they keep a backup source of water. These respondents spend $100 per year on bottled water sources. Most of the respondents do not belong to any watershed protection group.

Table 1 Sociodemographic profile of the respondents (N=1250)[18]

Sociodemographic variable	% in sample	Sample mean
Age (years)		50.1
Under 30	12.42%	
31-50	35.94%	
51-70	43.63%	
>70	8.69%	
Education level		
High school and below	16.64%	
College/technical school	37.52%	
University/postgraduate	44.56%	
Gender		
Male	48.80%	
Female	51.20%	
Annual household income (CAD)		\$179,000 (125,000)[a]
Less than \$50000	4.96%	
51000-149999	52.08%	
150000 and above	32.08%	
Refused to answer	10.88%	
Household size		2.65
Under 3	57.78%	
3 and above	42.21%	
Residential status		
Rent	22.64%	
Own	77.37%	
Payment of water bills		
Yes	83.44%	
No	16.55%	
Member of watershed protection group		
Yes	2.16%	
No	97.84%	
Amount spent on backup source of water (CAD)		100.42**
Under 20	27.61%	
20-100	51.50%	
>100	20.93%	

Notes: ** This amount is based on the number of respondents who keep backup water sources and not the entire sample. [a]Median income is presented in parenthesis

[18] These results were weighted to account for the oversampling of rural respondents.

Table 2 compares gender, age, household size, residential status and income of respondents in the survey with the 2011 Canadian census results for Alberta (Statistics Canada 2011). This helps examine the representativeness of our sample in terms of observable characteristics and address any sample related bias. However this may not mean that our sample is unbiased as people can differ by unobservable characteristics. The distribution of gender in the sample is relatively close to the distribution of gender in the Albertan population. For instance about 51% of respondents in our sample are females whereas the provincial percentage of females is about 50%. Age distributions appear to be different except for ages greater than 70 years. About 9% of respondents in our sample are over 70 years old whereas about 7% of such respondents are in the province. The household sizes in the sample are closer to the household sizes in the Canadian census for Alberta results. About 58% of households in our sample have fewer than 3 members compared to the provincial percentage of about 59%. Also the ownership status of respondents in their places of residence is close. Both samples indicate that most respondents own their places of residence. Household income levels ranging between $51000 and $149999 are also close for both datasets. Overall our sample is comparable to the Albertan population in gender, household size, residential ownership status and some categories of income.

Table 2 Comparison of some sample demographic information with the 2011 Canadian census for Alberta

	Sample %	Provincial %
Gender		
Male	48.8%	50.1%
Female	51.2%	49.9%
Age[a]		
18-30	12.42%	6.4%
31-50	35.94%	29.5%
51-70	43.63%	21.5%
>70	8.69%	7.1%
Household size		
Under 3	57.78%	58.96%
3 and above	42.21%	41.04%
Residential status		
Own	77.37%	73.55%
Rent	22.64%	25.74%
Other	-	0.71%
Income		
Under $50000	4.96%	30.31%
51000-149999	52.08%	52.01%
150000 and above	32.08%	17.77%
Refused to answer	10.88%	-

Notes**:** [a]The provincial age distribution does not add up to 100%. In the comparison we exclude ages below 18 years because such individuals cannot participate in our survey. The remaining percentages reflect ages less than 18.

5.2 Respondents' opinion on environment and development goals

The introductory section of the survey presented respondents with different statements regarding environment and development goals. They were asked to rank these statements on a 5 point Likert scale in an increasing order of agreement. "5" denoted strong agreement to the statement whereas "1" denoted strong disagreement. The order of these questions was randomized across the sample.

Table 3 presents the respondents' ranking of the statements regarding environment and development goals. About 46% of the respondents agree that environmental improvement programs that would be harmful to businesses should be carried out where as about 20% of the respondents agree that such improvement programs should not be carried out. This shows that most of the respondents care about their immediate environment and want it improved when required although the improvements might affect businesses. However most of these respondents do not like environmental programs that include increases in their taxes.

On average, most of the respondents also disagree that environmental issues should be solved by experts and that the public will only serve as information recipients. It is therefore evident that Albertans want to be involved in the decision making process regarding their immediate environment. Only about 21% of the respondents agree that the public should only be educated and informed about decisions regarding environmental issues. In terms of how environmental issues can be dealt with, about 40% of the respondents think new technologies can help. They therefore support investments of public funds into new technologies that can help solve environmental issues.

Interestingly most of the respondents believe that humans will be able to control natural processes in the future. This can be attributed to the influx of technologies and their support for investments in these technologies. They therefore believe that human progress is limited by technology and not by the environment.

Table 3 Respondents' opinion on environment and development goals (N=1250)

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Environmental improvement programs that would be harmful to business should not be carried out	17.60%	28.48%	33.92%	12.56%	7.44%
Environmental improvements are fine as long as taxes do not increase	8.96%	19.36%	34.88%	21.20%	15.60%
Experts should solve environmental issues and the public should only be educated and informed of the decisions	25.68%	24.96%	27.44%	15.12%	6.80%
New technology will solve most environmental problems	12.40%	25.44%	36.24%	20.32%	5.60%
In the future, humans will be able to understand and control most natural processes	17.92%	26.96%	33.92%	16.16%	5.04%
Human progress is limited only by technology and not by the environment	24.16%	31.20%	26.96%	12.96%	4.72%

5.3 Respondents' experiences with, and risk perceptions of, water outages

This section begins with a description of some water quality and reliability challenges experienced by respondents in the year 2014. The section then presents numerical amounts of short-term outages, longer-term outages and BWAs experienced by these respondents in the last 10 years. These numerical amounts of outages are compared for rural and urban residents of Alberta. The section also presents the respondents' numerical risk perceptions of future water reliability in their communities.

5.3.1 Water quality challenges experienced by respondents in the year 2014

Table 4 presents the various water quality challenges experienced by the respondents in the year 2014. Overall, about 33% of the respondents claim they did not experience water quality challenges in the year 2014. 3.6% of the respondents have experienced other water quality challenges than the ones presented in the survey.

About 11% of the respondents claim to have found sediments in their home tap water. The predominant water quality challenge relates to the presence of mineral deposits in the water resulting in hardness of the water. About 27% of the respondents also experienced unpleasantness in the smell and taste of water from their home tap system. The unpleasantness may be as a result of the presence of excess chlorine. Finally about 13% of the respondents experienced water quality challenges in the form of low water flow.

Table 4 Water quality challenges experienced by respondents in the year 2014

Water quality challenge	Percentage
Rusty Colour	6.08
Sediment	10.88
Unpleasant Smell	27.44
Unpleasant Taste	22.24
Hard water/mineral deposits	45.52
Pollutants or other contamination	2.72
Low water flow/Insufficient water pressure	12.88
Other	3.60
No water quality challenge	32.80

Notes: Percentages do not add up to 100% because respondents could select multiple water quality challenges.

5.3.2 Water reliability challenges experienced by respondents in the year 2014

Different statements on loss of tap water services in the last year (2014) were presented to the respondents to select ones applicable to their household. Table 5 presents proportion of respondents in the sample that experienced any of those tap water reliability challenges.

Overall about 66% of the respondents claim they did not experience any loss of tap water services in the year 2014. However 13.2% of the respondents had their tap water services cut off for some period of time. About 6% of the respondents experienced advisories issued either as a precaution or response to water borne diseases. 6.2% of the respondents did not drink their tap water because of it smell and colour. A relatively small proportion of the respondents claim not to have consumed water from their tap because of some other reasons than the ones presented in the survey.

With regards to the intensity of inconveniences caused by these types of water outages, about 60% of the respondents claim these were minor inconveniences. About 23% of them claim the inconveniences were significant whereas only a few of them said water outages caused no inconveniences. This emphasizes the importance of water and the need to invest in programs that will reduce these inconveniences.

Table 5 Respondents' experiences with loss of tap water service in the year 2014

Incident	Percentage
Tap water was unavailable (cut off) for some period of time	13.20
Boil water advisory was issued	5.84
We were unable to obtain tap water for other reasons	14.96
We didn't drink the tap water because of smells, colour or some other reason – even though there wasn't an official advisory	6.24
There was a water use restriction like a lawn watering restriction or some other public restriction or advisory asking for reduced water use	9.68
We have not experienced any loss of service to our tap water in the past year	65.76

Notes: The row percentages do not add up to 100%. This is because some respondents experienced more than one of these types of water outages in the year 2014.

5.3.3 Numerical amounts of water outages experienced by respondents in the last 10 years

The survey asked the respondents to provide numerical amounts of short-term outages, longer-term outages, and boil water advisories they have experienced in the last 10 years. Table 6 presents the numerical amounts of these types of water outages experienced by respondents. More than half of the respondents claim to have not experienced short-term water outages in the last 10 years. The average number of short-term water outages experienced is about 1. About 35% of the respondents experienced 1 to 10 times of short-term water outages in the last 10 years. About 0.3% of the respondents experienced more than 10 short-term water outages in the last 10 years

Again about 85% of the respondents have not experienced any longer-term water outages in the last 10 years. Only about 15% of them experienced positive number of longer-term outages in the range of 1 to 10 times in the last 10 years. The story is not different for experiences with boil water advisories by these respondents. The survey results indicate that about 81% of the respondents did not experience any boil water advisories in their respective communities in the last 10 years. Only about 18% of them claim boil water advisories were issued in their communities. The average number of boil water advisories experienced in the last 10 years is approximately 1. All these results are a testament to the current reliability of drinking water in Alberta.

Table 6 Respondents' numerical experiences with water outages in the last 10 years

Type of water outage	Number of times experienced			
	0	**1-10**	**>10**	**Mean**
Short-term unexpected water outage	63.84%	35.20%	0.16%	**0.97**
Longer-term unexpected water outage	84.92%	14.83%	0.24%	**0.38**
Boil water advisory	81.42%	18.25%	0.32%	**0.57**

These numerical amounts of water outages experienced in the last 10 years are compared across different geographic locations in Alberta in the following section.

5.3.3.1 Comparison of water outages experienced by rural and urban residents

The survey results indicate that the mean number of short-term water outages experienced by rural community residents is about 2 whereas urban residents experienced only 1 of such outages in the last 10 years. In order to test the statistical significance of the difference in the mean number of water outages experienced in rural and urban communities, a two-group mean *t*-test was conducted. The results of the test indicated a statistically significant difference between the number of water outages.

However with respect to the number of longer-term outages and boil water advisories experienced, the survey results indicate an almost equal amount of outages. This is supported by the mean comparison test which indicates no differences between the two means. These results are presented in Table 7.

Table 7 *t*-test results for mean difference of water outages experienced by rural and urban residents of Alberta

Type of water outage	Number of times experienced		
	Rural mean	**Urban mean**	***t*-score**
Short-term unexpected water outage	1.56	0.87	**4.00**
Longer-term unexpected water outage	0.41	0.36	**0.26**
Boil water advisory	0.68	0.52	**0.59**

Notes: Because rural observations were oversampled the mean outages for rural respondents were weighted to account for the oversampling.

5.3.4 Numerical risk perceptions of water outages in the next 10 years

The survey also elicited respondents' perception of numerical and subjective risks of the three types of water outage events in the next 10 years. In order to ensure that respondents understood the tool of water outage risk perception elicitation, a scenario of two community choices they could live in was presented to them. One community faced 2 water outages in 10 years where as the other community faced a 30% annual chance of water outages in the next 10 years. The respondents were then asked to select which community they would choose to live in. About 91% of the respondents selected the first community which faced only two water outages. This gives an indication that most of the respondents understood the risk elicitation tool and will live in a community with less risk of water reliability challenges.[19]

Table 8 presents the respondents' perception of the percentages of water outages they expect in the next 10 years. Surprisingly about 78% of the respondents expect positive percentages of short-term water outages in the next 10 years despite experiencing a few of such outages in the last 10 years. About 49% of them expect 1-20% annual percent chance of short-term water outages in the next 10 years. About 29% of them also expect more than 20% chance of short-term water outages. The mean annual percent

[19] The econometric models presented in chapter 6 were analyzed with and without these respondents that answered this question incorrectly. The model results do not differ.

chance of short-term water outages for the sample is about 24% indicating that Albertans on average expect 2 short-term water outages per year over the next 10 years.

About 55% of the respondents also expect positive percentages of longer-term water outages and boil water advisories in the next 10 years. The mean annual percent chance of longer-term water outages is about 8% whereas the mean percent chance of boil water advisories in the next 10 years is about 10%.

Table 8 Respondents' numerical risk perceptions of water outages in the next 10 years

Water Outage /Expectation (%)	0	1-20	>20	Mean%
Short-term water outage	22.50%	48.67%	28.81	**24.40**
Longer-term water outage	45.56%	44.68%	9.76%	**8.37**
Boil water advisory	45.88%	41.47%	12.64%	**9.74**

5.3.4.1 Comparison of water outage risk perceptions among rural and urban residents

A two group mean *t*-test was conducted again to test for the differences in means of the water outage risk perceptions among rural and urban residents of Alberta. The results of the comparison indicate that rural and urban residents of Alberta perceive just about the same percent chance of short-term risk to the reliability of drinking water in their respective communities per year over the next 10 years. For instance, rural residents on average expect about a 25% annual chance of short-term outages whereas urban residents expect about 24% chance of the same outage. The t score is 0.43 indicating no statistical difference between these two averages

Similarly, rural and urban residents of Alberta expect annual chances of longer-term water outages of about 8.49% and 8.30% respectively. The t score here also indicates no statistical difference between the two means. The results of this mean comparison are depicted in Table 9.

Table 9 Comparison of urban versus rural respondents' expectations of water outages in the next 10 years

Type of water outage	Mean Percentage expectations		
	Rural mean	**Urban mean**	***t*-score**
Short-term unexpected water outage	24.97	24.15	**0.43**
Longer-term unexpected water outage	8.49	8.30	**0.21**
Boil water advisory	9.92	9.66	**0.24**

5.4 Chapter summary

This chapter has presented demographic information about respondents in the survey. This demographic information is also compared with the 2011 Canadian census results for Alberta. The comparison indicated that our sample is comparable with the Albertan population in gender, household size and ownership of current place of residence. The chapter has also presented respondents' experiences with different types of water outages in the last 10 years. The results indicate that households in Alberta have not experienced many water reliability challenges in the last 10 years. This is a testament to the current reliability of water in Alberta. In addition, the chapter has also presented results of respondents' numerical risk perceptions of different types of water outages in the next 10 years. These estimates indicate that Albertans expect deteriorations in their future water supply and may suggest a need for investments to remedy this situation.

The following chapter presents the frequency of the responses to the valuation questions presented in the survey and parametric analysis of these responses.

CHAPTER SIX: RESULTS OF VALUATION QUESTIONS

6.0 Introduction

This chapter presents the results of the two valuation questions. The frequency of the responses to the valuation questions is presented. The frequency is compared across some demographic categories to examine observed preference heterogeneity. The chapter also presents results of parametric analysis of the valuation questions. The chapter in addition reports results of spike models that account for the presence of the proportion of respondents who are not part of the contingent market for water reliability risk reduction because of a lack of perceived water reliability risks. Results of random effects probit models using both exogenous and potentially endogenous measures of water reliability risk reduction are presented. Also the chapter presents results of models that attempt to account for the presence of endogenous variables in the utility model using the control function approach. The chapter concludes with a discussion about welfare measures that are obtained from the different model specifications.

6.1 Frequency of responses to the valuation question

This section presents the frequency of the responses to the two valuation questions presented to the respondents in the survey. The frequencies are presented based on the bid amounts and the method of water reliability improvement. Results are also presented for heterogeneity in responses to the valuation questions based on community sizes. The section also presents the frequency of responses to the valuation questions after adjustments for uncertainty of response. The section concludes with a description of the reasons for the respondents' choice of responses to the valuation questions based on the debriefing questions.

6.1.1 Frequency of responses from the CV scenario

As discussed above the contingent valuation question was presented to respondents with positive short-term water reliability risk perceptions. About 78% of respondents in the sample received this valuation question. Figure 8 presents the results of the responses to the contingent valuation question based on the bid amounts presented to the respondents. Overall about 45% of the respondents who received this valuation question voted in favour of the alternative management program that will reduce their risk of a short-term water outage relative to the status quo. The results also indicate that the respondents are more likely to vote for the alternative management program that will reduce short-term water outage risk perceptions at lower costs (bid amounts) of the program as one would expect. The statistical significance of this relationship is explored below. Furthermore, Figure 8 also provides some insight into the nonparametric median WTP (somewhere between $10 and $50 per year).

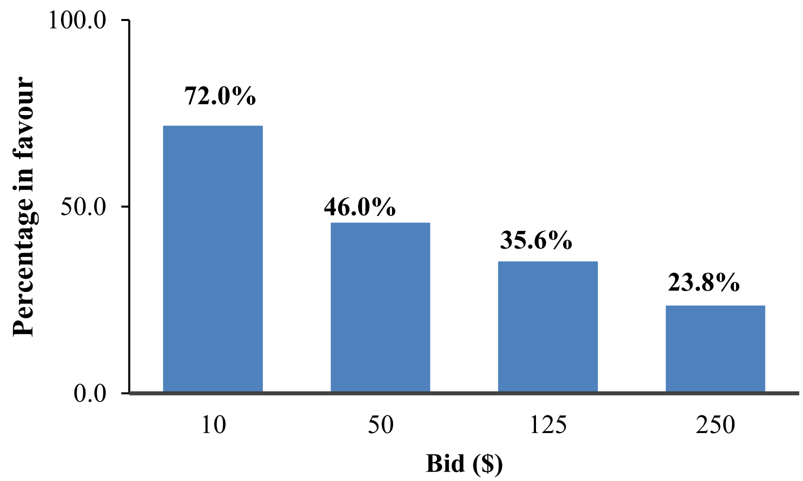

Figure 8 Percentage of respondents' votes in favour of the proposed program in the contingent valuation scenario by bid amount

Figure 9 depicts the results of responses in favour of the alternative management program to reduce short-term water outage risk perceptions based on the bid amounts and community sizes. The three community sizes are; "less than 15,000 residents", "between 15,000 and 100,000 residents", and "more than 100,000". There is not much heterogeneity in the responses by community sizes. A relatively higher proportion of respondents living in communities with more than 100,000 residents tend to vote for programs that will reduce their short-term water outage risk perceptions at lower costs. At higher costs (for example $250 per year), a relatively higher proportion of respondents living in communities with less than 15000 residents tend to vote in favour of the proposed alternative management program.

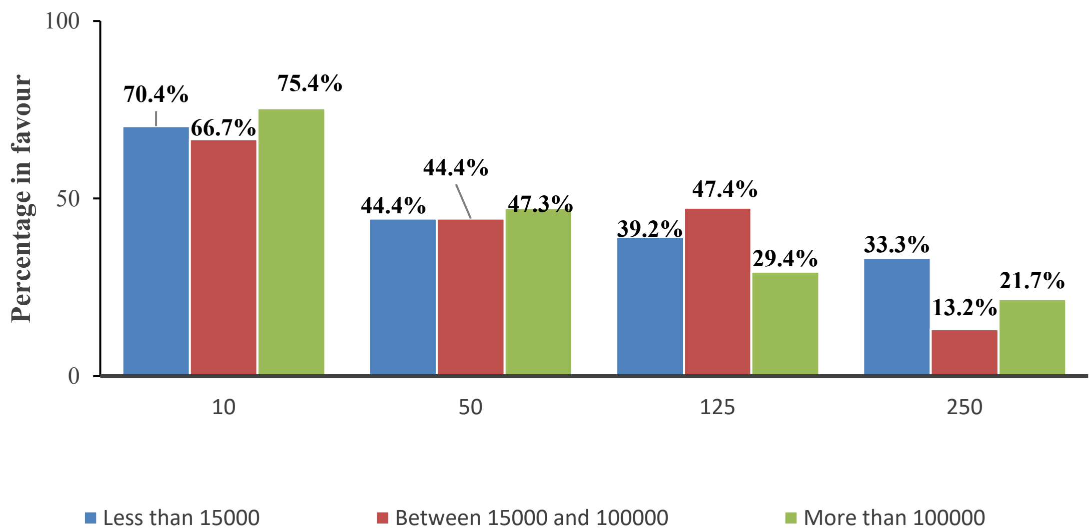

Figure 9 Percentage of respondents' votes in favour of the proposed program in the CV scenario by bid amounts and community size

6.1.2 Frequency of responses from the hybrid valuation scenario

Figure 10 presents the responses in favour of the proposed management program in the hybrid valuation question based on bid amounts and method of reliability improvement. It appears that the responses in favour of the valuation question depending on the bid amount and the method of reliability improvement are mixed. Some respondents prefer traditional water treatment infrastructure at certain bid amounts whereas others prefer forest and watershed management at other amounts. For instance, when the bid is $50 more respondents prefer watershed management while when the bid is $10 more respondents appear to prefer traditional infrastructure. Thus it's difficult to see any systematic preference for one versus the other.

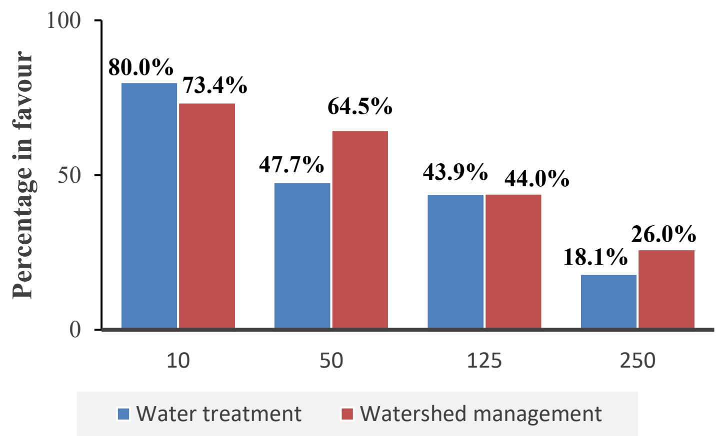

Figure 10 Percentage of respondents' votes in favour of the proposed program in the hybrid valuation scenario by bid amount and method of reliability improvement

Again, in order to identify any observed heterogeneity in the responses to this valuation question, we present the frequencies by community sizes and bid amounts in Figure 11. Compared to respondents living in medium-sized communities, a relatively higher proportion of respondents living in smaller and larger-sized communities tend to vote for the management program at low bid amounts. The difference between these votes may not be statistically significant.

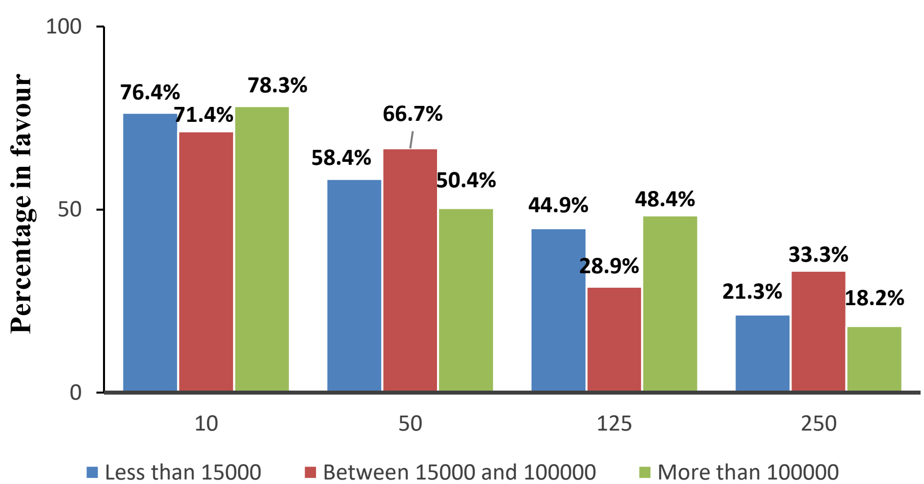

Figure 11 Percentage of respondents' votes in favour of the proposed program in the hybrid valuation scenario by bid amount and community sizes

6.1.3 Comparison of responses to valuation questions by bid amount before and after certainty adjustment

Responses to the certainty questions presented at the end of each valuation question were used to recode responses in favour of the valuation questions but below certain levels of certainty. As a description when a respondent votes in favour of the proposed program but they indicate a low certainty level of how they would vote in an actual referendum, their responses are changed into votes against the program. This is because they are likely to vote against the program in an actual referendum. Certainty adjustment therefore reduces the disparity between the real and hypothetical valuation of a good (Champ et al. 1997; Blumenschein et al. 1998; Blumenschein et al. 2008).

Using the 5-point certainty scale presented above, we changed the votes in favour of the proposed management program but below a certainty level of 4, to votes against the program. Figure 12 presents the impact of this certainty adjustment on the responses in favour of the alternative management program presented in the CV scenario. There is a substantial reduction in the votes for the program at different bid amounts.[20] Not adjusting for certainty may lead to overestimation of the value of the environmental good.

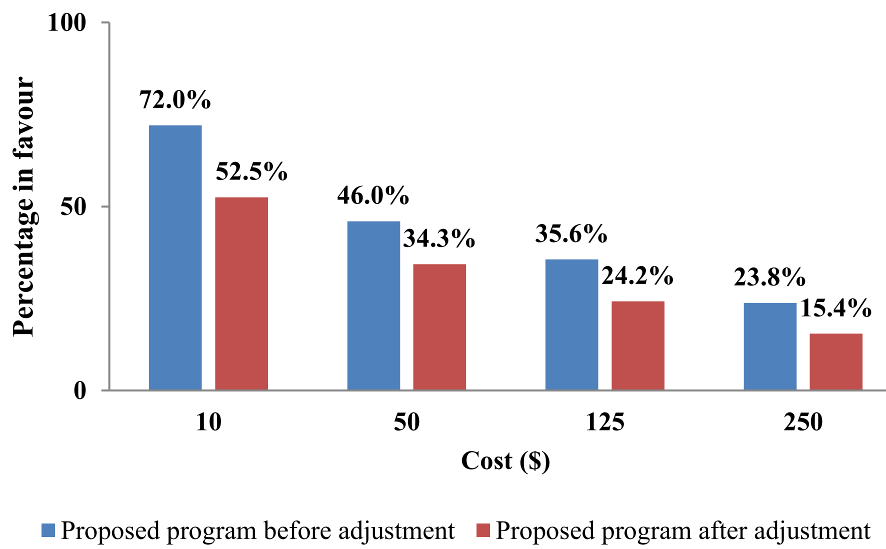

Figure 12 Percentage of respondents' votes in favour of CV question before and after certainty adjustment

[20] Similar results were obtained when certainty adjustment was applied to the responses in favour of the management program in the hybrid valuation scenario.

6.1.4 Reasons for respondents' choice of votes

The responses to the different debriefing questions presented after each valuation question were compared with the responses to the valuation questions in order to understand the reason behind the respondents' choices. About 43% of the respondents voted for the alternative management program presented in the contingent valuation scenario because they believed that the program will actually help to make water supplies more reliable. 21.7% of the respondents voted against the program because they do not believe in the program reducing reliability challenges. 38.4% of the respondents voted for the program because they support any expenditure that will make water supplies reliable. Conversely, 32.2% of the respondents voted against the program because they do not support expenditures aimed at reducing water reliability challenges. 31.6% of the respondents voted against the alternative management program that will reduce their risk of short-term water outages because they do not believe that their individual votes in hypothetical referendums can impact policy. Finally about 40% of the respondents voted against the proposed management program because they claim their communities' water supplies are reliable enough.[21]

After the presentation of the hybrid valuation question, respondents were asked to rank how the various types of water outage events mattered in their voting choices. About 37% of the respondents claim reductions in annual percent chance of longer-term water outages mattered most in their choice of vote. These are followed by reduction in short-term outage risks and finally boil water advisories. It is important to emphasize the relative percentages of these rankings are not statistically significant. Hence each of these reliability challenges is important to the respondents during selection of management program options.

Finally, respondents were asked to rate what extent they believe government resource management to take their interests into account after responding to the valuation questions. Interestingly 56.8% of the respondents voted in favour of the proposed management programs because they believe government officials will take their views into account during policy formulation. About 30% of the respondents voted against the

[21] The percentages presented here do not add up to 100% because respondents could choose multiple reasons in the survey.

programs because they do not believe that officials will value their views in policy formulation.[22]

6.2 Parametric analysis of the responses to the valuation questions

This section presents parametric estimates of the econometric models described in chapter 3 and estimated using the choice data discussed above. The section begins with a description of the variables used in the different econometric models. The first set of parameter estimates are from spike models that included all respondents in the sample regardless of their water outage risk perceptions. The section then presents results of random effects probit models that used only respondents with positive numerical risk perceptions of water outages. In addition the section presents control function mixed logit model results that attempt to account for the potential endogeneity of the three absolute risk reductions of water outages. The section concludes by describing the welfare measures obtained from all these models. It is important to mention that all the parametric analyses were carried on the survey data without adjusting for response uncertainty.

6.2.1 Description of variables

The responses to the CV and the hybrid valuation questions were jointly analyzed because they share a common theoretical framework, the random utility model. This joint analysis of both votes provides two observations per individual and may therefore increase the robustness of models estimated (Adamowicz et al. 1997). The hybrid valuation question had more attributes of the proposed management program than the CV question. We assume that the attributes not present in the CV question are constant for the respective respondents to facilitate the joint estimation of the models. The potential for correlation between the errors terms of the two sets of responses is also accounted for in the estimation.

Table 10 presents a description of the variables used in different econometric model specifications. The variable *cost* represents the various bid amounts presented to the respondents as the costs of the proposed alternative management program to reduce risks of water reliability challenges. The previous chapter established a relationship

[22] A "policy consequentiality test" can be carried out on the survey data without this group of respondents. However that is beyond the scope of this thesis.

between the bid amount and the probability of votes so it is important to test the statistical significance of this relationship.

The level of exogenous risk reduction presented to the respondents is represented by the variable *relative.* As discussed above two levels of exogenous water outage risk reduction levels were presented to the respondents. This dummy variable represents these risk reduction levels with 1 representing a 99% exogenous risk reduction and 0 representing a 50% exogenous risk reduction. This variable is used to test the sensitivity of the value of drinking water reliability to scope.

Absolute measures of risk reductions were also computed and included in model specifications. These will help examine the WTP for numerical amounts of water outage risk reductions. Absolute risk reduction of short-term outages, absolute risk reduction of longer-term water outages and absolute risk reduction of boil water advisories were computed from the respondents' self-reported numerical risk perceptions and the levels of exogenous risk reduction presented to them in the survey. For example if a 50% exogenous risk reduction is presented to the respondent and they perceive a 25% chance of a short-term outage, then their absolute risk reduction of a short-term water outage is 12.5%. Similarly, if the exogenous risk reduction presented to the respondent is 99% and they perceive a 25% chance of a short-term water outage, then their absolute risk reduction is 24%. Descriptive statistics of these absolute measures of risk reduction show a mean of 18.1% for short-term risk reduction, 6.3% and 7.4% for longer-term and boil water advisory risk reduction respectively.

Again because the voting order was randomized, the variable *order* was created to test for order effects in the responses to the valuation questions. This will help determine whether responses to the valuation questions are contingent on the order in which the respondents receive the questions. The variable *order* is equal to 1 when the contingent valuation question was presented first to the respondent. Otherwise it is 0.

The hybrid valuation question had more attributes than the CV question as discussed above. The variable *vote_type* is added to models to account for differences in the number of attributes when the two voting responses were stacked together. This variable is therefore equal to 1 when the valuation question is the hybrid and 0 when the question is CV.

Table 10 Description of variables used in different econometric model specifications

Variable	Description
Cost	Cost of the proposed program ($) per year
Relative	Exogenous risk reduction (1=99% reduction; 0=50% reduction)
Short term risk	Absolute risk reduction of short term outage (%)
Longer-term risk	Absolute risk reduction of longer-term outage (%)
BWA risk	Absolute risk reduction of boil water advisory (%)
Order	Order in which vote is presented to respondent (1=first vote;0 = otherwise)
Vote_type	Type of valuation question (1=CV; 2=hybrid)

6.2.2 Weights

All the regression models presented in this chapter are weighted to account for the oversampling of rural respondents in the survey. Rural and urban observations had different probabilities of being in the sample because the former was oversampled. The oversampling produced three times rural communities' observations than reflected in the actual population. Hence each rural community observation is assigned a weight of 0.37 (i.e., the ratio of the number of rural community observations needed for the random sample to the total number of rural observations in the dataset). The terms in the log likelihood function and their respective derivatives are multiplied by the variable "weight" which is equal to 1 for urban observations and 0.37 for rural observations (Greene 2012). The weights are scaled automatically to sum up to the current sample size (Greene 2012).

6.2.3 Results from spike models

As discussed above the valuation questions were presented to respondents with positive water reliability risk perceptions. However about 21% of the respondents did not receive any of the valuation questions because they had zero water outage risk perceptions. They are considered out of the contingent market for valuation of drinking water reliability risk reduction. Implicitly respondents in this group have zero WTP. We used Kristrom's simple spike model discussed above to allow these respondents to have non-zero probability of zero WTP (Kristom 1997). This would reduce any selection issues that could make our welfare measures unrepresentative of the Albertan population. We also made different distributional assumptions about WTP as robustness checks. The first distributional assumption was the logistic distribution just as in Kristrom (1997). We also assumed the normal distribution to be able to compare with the logistic distribution. The log-normal CDF was also assumed to restrict WTP to only the positive axis recognizing that a problem of "fat tails" may arise with this assumption.

Table 11 reports the results from these different specifications for all respondents in the survey regardless of their water reliability risk perceptions. It is important to note that models presented in this table only use exogenous covariates. The first column presents the results of the simple spike model assuming a logistic CDF. The second column presents parameter estimates from spike models that assumed a normal CDF. The last column results were estimated assuming a lognormal CDF for WTP.

Model results for the three distributions assumed have similar coefficient significance and signs. The coefficient on *constant* is positive and statistically significant at 1% across all the different distributional assumptions indicating preference for the proposed management program to reduce water reliability risk perceptions relative to the status quo. The marginal utility of money represented by the coefficient on *cost* is also positive and statistically significant across all the different model specifications. This indicates that across all model specifications, the probability of a vote in favour of the proposed alternative management program increases with decreases in the bid amounts. *Vote_type* is positive and significant across all the different model specifications to account for additional value to the hybrid valuation scenario relative to CV. Again across the different model specifications there is the absence of order effects in the responses to the valuation questions.

As discussed above the "spike" is the probability that WTP is zero. The spike was estimated across all the different distributional assumptions. The estimated spikes are 0.258, 0.217 and 0.160 for the logistic, normal and lognormal CDFs respectively. Compared with the actual proportion of respondents with zero WTP in the sample (0.212), the logistic CDF appears to overestimate the spike. The normal CDF however correctly estimates the spike as there is no statistical difference between this estimate and the "actual" spike. The lognormal distribution on the other hand underestimates the spike.

Table 11 Results of spike models that included respondents who were out of the contingent market for water outage risk reduction because of a lack of perceived risk

	Model 1 (Logistic WTP)	**Model 2 (Normal WTP)**	**Model 3 (Log-normal WTP)**
	Coefficient (Std. Error)	Coefficient (Std. Error)	Coefficient (Std. Error)
Constant	0.9773***	0.6433***	0.8629***
	(0.0753)	(0.0443)	(0.0458)
Cost	0.0205***	0.0111***	0.3572***
	(0.0005)	(0.0006)	(0.0098)
Exogenous risk	0.0523	0.0077	0.0167
	(0.0702)	(0.0401)	(0.0393)
Vote type	0.2378***	0.1376***	0.1336***
	(0.0702)	(0.0401)	(0.0392)
Order	0.0776	0.0400	0.0474
	(0.0821)	(0.0475)	(0.0461)
Estimated Spike	0.258	0.2174	0.160
	(0.018)	(0.013)	(0.011)
Actual spike[a]	0.212	0.212	0.212
No. of Observations	2500	2500	2500
Log likelihood	3541.16	3593.40	2895.52

Notes: *** indicates statistical significance at 1%. [a]Actual spike is the proportion of respondents in the survey that did not receive the valuation questions because of a lack of perceived risk to drinking water reliability.

6.2.4 Random effects probit model results

The econometric models presented above used the entire survey data, including respondents who perceived no risks to the reliability of their drinking water. However, the econometric models presented in this sub-section were estimated using respondents with only positive water reliability risk perceptions. This would help us to estimate welfare measures that are conditional on water outage risk perceptions. The random effects probit model developed in equation (13) is used to model the effect of program attributes on the probability of vote in favour of proposed programs to reduce the risk of water outages. We first present results from models using the exogenous risk reduction and then employing the potentially endogenous absolute risk reductions.

6.2.4.1 Models using exogenous risk reduction

Four random effects probit models for different portions of the sample with positive risk perceptions were estimated using the exogenous risk reductions. In each model, the probability of a vote in favour of the proposed alternative program to reduce the risk of short-term and longer-term water outages, and boil water advisories is estimated as a function of the cost of the program, the level of exogenous risk reduction, the type of vote, the order in which the valuation question was presented and a variable that accounts for unobserved preference heterogeneities, *rho.*

Table 12 reports the results of the estimation of these different specifications. The first column presents results of the random effects probit model using the total sample of respondents with positive risk perceptions. The second column presents the results of estimations using the portion of the sample with more than 20% short-term water reliability risk perception levels because that portion may be more sensitive to risk reductions. The third and fourth columns present model results for rural and urban samples only respectively.

All the coefficients enter model 1 with the expected signs. The coefficient on the constant is statistically significant at 1% indicating a preference for the proposed management program to reduce risks of water outages relative to the status quo. The model results also indicate a negative and statistically significant relationship between the cost of the proposed management and the probability of a voting for the proposed program. This means that respondents are more likely to vote for the alternative program relative to the status quo at lower costs of the program. However the coefficient on the exogenous risk variable, although positive indicating preference for a 99% risk reduction relative to a 50% reduction, is not statistically significant. This suggests a lack of sensitivity to scope. The coefficient on the *vote_type* variable is positive and statistically significant indicating that the hybrid valuation question has more attributes and, these additional attributes will give the program a higher WTP relative to the CV program. The *order* variable is statistically insignificant indicating that responses to the valuation questions are insensitive to the order in which the questions are presented to the respondents. There are therefore no order effects in the response to programs that will reduce the risk of water outages in Alberta. Finally the coefficient on *rho* is statistically significant at 1% signalling the presence of unobserved preference heterogeneities in the sample.

The results of the first model showed that the overall sample is insensitive to the amount of exogenous risk reductions. However, this overall insensitivity could be because respondents with low risk perceptions of water outages may not perceive a difference between the two exogenous risk levels. Using the short-term water outage risk perceptions as a criterion because it is common to both valuation questions, different lower levels of risk perceptions were rejected. The results presented in model 5 reject individuals with risk perceptions less than 20%. The coefficient on the constant is again positive and significant indicating preference for the management program to reduce water outage risks relative to the status quo. The coefficient on cost is also negative and significant indicating that the probability of votes for the proposed management program increases as bid amounts decreases. Interestingly the coefficient on exogenous risk reduction is positive and statistically significant. This indicates that respondents who expect higher water outage risks prefer programs that will reduce their risk by higher amounts relative to smaller amounts. This suggests an evidence of scope sensitivity to the environmental resource being valued. The coefficient on vote type is again positive and statistically significant. The coefficient on *order* again signals the absence of order effects in the responses to the valuation questions. Again the coefficient on *rho* is statistically significant to signal the presence of unobserved heterogeneities in the sample

Model 6 presents the parameter estimates of the random effects probit model using the sample of rural respondents only. The results indicate that rural respondents also prefer programs that will bring improvements to their drinking water supply reliability relative to the status quo. They are also sensitive to increases in the cost of the program and tend to vote against the proposed alternative program at higher costs. The coefficient on the exogenous risk variable is negative and statistically insignificant. This indicates lack of scope sensitivity of rural residents to the magnitude of water outage risk reduction. Interestingly the coefficient on the *order* variable is positive and statistically significant. This means that rural respondents' valuation of water reliability risk reducing programs depends on the order in which the various programs are presented. In effect the value of the program presented in the CV scenario will be higher in situations when it appeared first in the sequence. Because of this effect, the coefficient on vote type is statistically insignificant. This implies that the additional attributes of the hybrid program does not add on to its value. The coefficient on *rho* is significant to signal the presence of unobserved heterogeneities in the rural sample.

The final column of Table 12 presents the results of the random effects probit model using the sample of urban respondents. Here again, the coefficient of cost and constant are similar and have same impacts as discussed above. Exogenous risk reduction is also positive just as for the full sample but not statistically significant. This gives an indication that urban respondents' valuation of water reliability programs is insensitive to the magnitude of risk reduction. The coefficient on *order* is negative and insignificant indicating no order effects. However, in contrast to the results from the rural sample, the presence of more attributes in the hybrid valuation scenario adds on to the value of the water reliability improvement program presented. This is depicted by the positive and statistically significant coefficient on *vote type*. The coefficient on the variable *rho* is significant at 1% to indicate presence of unobserved preference heterogeneities in the urban sample.

It is important to mention that the separate analysis of rural and urban respondents respectively did not show any sensitive to scope likely because we did not reject respondents with less than 20% risk perceptions. We performed a likelihood ratio test to check if there are any statistical differences between parameter estimates of urban and rural models. The chi-square statistic was 15.18. Hence we reject the null hypothesis of parameter equality at 5% level of significance and conclude that rural and urban models are statistically different.[23]

Table 12 Results of random effects probit models that used only exogenous measures of risk reductions

	Model 4 (Total sample)	**Model 5 (Rejecting <20% short term risk perceptions)**	**Model 6 (Rural sample only)**	**Model 7 (Urban sample only)**
	Coefficient (Std. Error)	Coefficient (Std. Error)	Coefficient (Std. Error)	Coefficient (Std. Error)
Constant	0.7878***	0.5327**	0.8820***	0.7667***
	(0.1372)	(0.2332)	(0.2372)	(0.1661)
Cost	-0.0111***	-0.0082***	-0.0098***	-0.0113***
	(0.0007)	(0.0012)	(0.0014)	(0.0009)
Exogenous risk	0.0977	0.4422*	-0.2178	0.1575
	(0.1436)	(0.2438)	(0.2359)	(0.1754)
Vote type	0.3096***	0.3063**	0.1320	0.3440***
	(0.0866)	(0.1373)	(0.1468)	(0.1053)
Order	-0.-0.0141	-0.2319	0.6160***	-0.1162
	(0.1671)	(0.2806)	(0.2901)	(0.2032)
Rho	0.7543***	0.7579***	0.7044***	0.7610***
	(0.0292)	(0.0486)	(0.0625)	(0.0342)
No. of observations	1970	720	594	1376
Log likelihood	-1104.14	-418.38	-347.53	-764.20

Notes: *** , ** and * indicate significance at 1% , 5% and 10% respectively. Total sample represents the sample of respondents with only positive risk perceptions

[23] Swait and Louviere (1993) and Adamowicz et al. (1997) provide an explanation on hypothesis testing of model estimates from different sub-samples when the models have the same explanatory variables.

6.2.4.2 Models using potentially endogenous absolute risk reductions

Table 13 reports the results of random effects probit models using the potentially endogenous absolute risk reductions for different portions of the sample with positive risk perceptions. The first column presents the model results from the overall sample of respondents with positive risk perceptions. Model results using the rural sample only are reported in the second column. The final column reports model results using the urban sample of respondents with positive risk perceptions only. In each model, the probability of a vote in favour of the proposed program to reduce water outage risk perceptions is estimated as a function of the cost of the alternative program, the absolute risk reduction of short-term outages, the absolute risk reduction of longer-term outages, the absolute risk reduction of boil water advisories, the type of vote, the order in which the valuation question was presented and the variable that accounts for the presence of unobserved preference heterogeneities in the sample.

Results of the model using the sample of respondents with positive risk perceptions (Model 8) show a positive and statistically significant coefficient on the constant. This indicates that respondents prefer an alternative program that will reduce their absolute risks of short-term water outages, longer-term water outages and boil water advisories to specified percentages relative to the status quo. Again as expected the coefficient on cost is negative and statistically significant at 1% indicating that respondents prefer the status quo relative to the proposed program at higher costs of the latter. The coefficient on the short-term water outage absolute risk reduction although positive is not statistically significant. This indicates that respondents' vote for the proposed alternative management program is insensitive to the absolute risk reduction of short-term water outage. Similarly the votes for the program are insensitive to the absolute risk reduction of longer-term water outages. However, respondents' responses to the valuation questions are sensitive to the amount of boil water advisory risk reductions. They tend to vote for the proposed program when the percentage of boil water advisory risk reductions increases. The model results also show a positive and statistically significant relationship between the vote type and the vote responses. In effect, the additional attributes of the hybrid valuation scenario will add on to the value of this scenario. Finally the coefficient on *order* is statistically insignificant to indicate the absence of order effects in the responses to the valuation questions.

Model 9 shows that the constant and the cost of the program have similar impacts on the probability of votes in favour of the program among rural respondents. Rural respondents appear to prefer the proposed alternative program to the status quo and also prefer lower costs of the program. The coefficient on the absolute risk reduction of short-term water outages is statistically significant at 10%. This indicates that rural respondents appear to be more concerned about reductions in their short-term risk perceptions of water reliability challenges. They tend to vote for the program to reduce risks of reliability when the short term risk reductions are higher. However, the additional attributes of the hybrid valuation question do not seem to add on to its value in the rural sample as depicted by the insignificant coefficient on *vote type.* The order variable is statistically significant at 5%. This indicates that the value of the program in the CV scenario will be higher than that of the hybrid valuation scenario in situations where the former appeared first in the valuation sequence. Similar results were obtained when the exogenous levels of risk reductions were used as discussed above. The coefficient on *rho* is statistically significant at 1%. This indicates the presence of unobserved preference heterogeneities in the rural sample.

In model 10 that used only the urban sample of respondents, the coefficient on constant and cost are all significant at 1%. This indicates preference for the management program at lower costs relative to the status quo of drinking water reliability. The results also indicate a positive and statistically significant relationship between boil water advisories risk reduction and the probability of vote in favour of the proposed program. This indicates that urban respondents are sensitive to increases in the percentages of risk reductions of boil water advisories. However, contrary to what we observed in the rural sample, the responses to the valuation questions are not sensitive to the order in which they appeared to the respondents. This is reflected in the statistically insignificant coefficient on *order.* Again the value of the program presented in the hybrid valuation scenario is more than the CV alone because the former has more attributes. This is depicted by the positive and significant coefficient on *vote type.* The coefficient on *rho* is statistically significant to signal the presence of unobserved preference heterogeneities within the urban sample. It is important to mention that the nothing has been done to address the potential endogeneity of the absolute risk reductions in this section- see below for models that accounted for the potential endogeneity problems.

Finally results of the likelihood ratio test to check differences between parameters of the separate rural and urban models yielded a chi-square statistic of 177.84. We therefore reject the null hypothesis of equal parameters at 5% significance level and conclude that rural and urban models are statistically different.

Table 13 Results of random effects probit models that used potentially endogenous absolute risk reductions

	Model 8 (Total sample)	**Model 9 (Rural sample only)**	**Model 10 (Urban sample only)**
	Coefficient (Std. Error)	Coefficient (Std. Error)	Coefficient (Std. Error)
Constant	0.7362***	0.5616***	0.7656***
	(0.1347)	(0.2143)	(0.1650)
Cost	-0.0111***	-0.0096***	-0.0113***
	(0.0008)	(0.0014)	(0.0009)
Short term risk	0.0043	0.0087*	0.0034
	(0.0028)	(0.0046)	(0.0034)
Long term risk	-0.0042	0.0181	-0.0086
	(0.0066)	(0.0120)	(0.0082)
BWA risk	0.0094*	0.0037	-0.0110*
	(0.0054)	(0.0093)	(0.0065)
Vote type	0.2652**	-0.0362	0.3209**
	(0.1044)	(0.1710)	(0.1292)
Order	-0.0091	0.5792**	-0.1133
	(0.1668)	(0.2840)	(0.2033)
Rho	0.7533***	0.6865***	0.7612**
	(0.0292)	(0.0656)	(0.0341)
No. of observations	1970	594	1376
Log likelihood	-1101.53	-343.23	-847.22

Notes: *** , ** and * indicate significance at 1% , 5% and 10% respectively. Total sample represents the sample of respondents with only positive risk perceptions.

6.2.5 Accounting for the presence of endogenous variables in the utility model

The absolute short-term risk reduction, absolute longer-term risk reduction and the absolute boil water advisory risk reduction that were computed and included in econometric models above were suspected to be endogenous in our models. This is because these risk reductions were calculated from the respondents' self-reported risk perceptions and therefore we suspect that unobserved variables such as respondents' knowledge of, and attitudes towards, water outage risks may be correlated with these absolute risk reductions. These correlations could therefore produce inconsistent estimates for absolute risk reductions in our models. We expected the impact of absolute risk reductions on respondents voting behaviour to be underestimated because of these omitted unobserved variables. We employed the control function approach of endogeneity correction. The success of this approach is contingent on the validity of instruments.

6.2.5.1 Instruments

The control function approach to endogeneity correction requires valid instruments. A valid instrument must satisfy two conditions; relevance and exogeneity (Verbeek 2008; Wooldridge 2010; Petrin and Train 2010). The instrument must be relevant in the sense that it is highly correlated with the endogenous variables. The exogeneity condition requires that the selected instrument is uncorrelated with unobserved variables that predict the outcome variable, which is the probability of a vote in favour of a proposed alternative to reduce water outage risk perception in this application.

In this application we used the respondents' self-reported risks of internet service outages as instruments. We suspect that communities that experience water outages may also experience internet outages. We therefore expect the internet service outage and water outage risks to be correlated. Short-term and longer-term internet outages were selected as instruments for short and longer term water outages. Internet quality risk perceptions were selected as instruments for boil water advisory risk perceptions.

Summary statistics of the instruments indicate that respondents perceive a 32% annual chance of short-term internet outages in the next 5 years. They also expect on average a 12% annual percent chance of longer-term internet outages in the next 5 years.

Finally they expect a 45% chance of internet quality problems in the next 5 years. Note however that there are high variabilities in these internet risk perceptions in the sample.

Table 14 reports a Pearson correlation coefficient matrix of the instruments and the potentially endogenous absolute risk reductions of water outages. There is a 0.21 correlation between the absolute risk reductions of short-term water outages and the risk reduction of short-term internet outages. Similarly there is a 0.35 correlation between the risks of short-term water outages and internet quality risks. The correlation matrix also indicates a 0.16 correlation between longer-term water risk reduction and longer-term internet outage risks. Finally there is a 0.14 correlation between boil water advisories and internet quality risks. All the correlation coefficients below are statistically significant at a 1% level.

Table 14 Pearson correlation coefficient matrix of endogenous variables and instruments

	Short-term water risk reduction	Longer-term water risk reduction	Boil water advisory risk reduction
Short-term internet risk reduction	0.2135	0.1134	0.1396
Longer-term internet risk reduction	0.1341	0.1665	0.1433
Internet quality risk reduction	0.3523	0.0829	0.0761

Notes: The internet risk reductions are the instruments used in the first stage OLS regressions.

However we are unable to test the exogeneity of our instruments. This is because we do not observe the random component of the utility obtained from the choice of water reliability risk reduction programs. Internet and water services are controlled by separate entities in Alberta. Water utilities are often public utilities whereas internet service providers are private firms. Furthermore, there are often multiple internet service providers but usually one water utility provider. Therefore, we do not expect internet outages to be a determining factor in explaining the vote for programs that will reduce water outage risks. We therefore do not expect internet service outages to be correlated with unobserved variables that determine respondents' choice of water reliability risk reducing programs. However, it is difficult to ensure that our selected instrument is exogenous.

6.2.5.2 Estimation of models

As discussed above, the control function approach is a two-step estimation process (Imbens and Wooldridge 2007; Petrin and Train 2010). The first step is the estimation of the reduced form equations. Three reduced form equations are estimated for the three absolute risk reductions of water outages using OLS. In each of the reduced form equations, the respective numerical water outage risk reduction is regressed on the cost of the program and the three instruments discussed above. We considered different interactions of the instruments with sociodemographic variables as further robustness checks.

Table 15 reports the results of the three first stage equations. The first column reports results of the regression of the absolute risk reduction of short-term water outage on the three instruments and the cost of the proposed program. All the instruments enter the regression model with expected signs except the longer-term internet outage risk which is negative and statistically significant. The model results indicate a positive and statistically significant relationship between the risk reductions of short-term water outage and short-term internet outage risk. A similar relationship is seen for the internet quality risk. Measures of goodness of fit such as the r-squared and the F-statistic signal an overall significance of the regression model.

In model 12, the long-term water outage absolute risk reduction is also regressed on the three instruments and the cost of the proposed alternative to reduce water outage risk perceptions. All the instruments enter the model with signs that one would expect. The absolute risk reduction of longer-term water outages increases with increases in the risk of short and longer-term internet service outages. These increases are however insensitive to increases in the risk reduction of internet quality. The measures of goodness of fit are also statistically significant to signal overall significance of this model

The last column in Table 15 presents the first stage OLS regression model for the absolute risk reduction of boil water advisories. These reductions are sensitive to short and longer-term internet risks. Surprisingly they are not sensitive to internet quality which signals that internet quality might not be a good instrument for BWA risk reduction.

Table 15 Parameter estimates of the first stage OLS regression models in the control function approach

	Short term risk as dependent variable (Model 11)	Longer-term risk reduction as dependent variable (Model 12)	Boil water advisory risk reduction as dependent variable (Model 13)
	Coefficient (Std. Error)	Coefficient (Std. Error)	Coefficient (Std. Error)
Constant	13.4731***	2.1657***	2.5152***
	(1.0597)	(0.973)	(0.4938)
Cost	-0.0094	0.0020	0.0018
	(0.0061)	(0.0023)	(0.0028)
Instrument 1	0.0616**	0.0207*	0.0343***
	(0.0282)	(0.0106)	(0.0132)
Instrument 2	-0.0006	0.0870***	0.0965***
	(0.0460)	(0.0172)	(0.0214)
Instrument 3	0.2709***	0.0084	0.0052
	(0.0220)	(0.0082)	(0.0102)
No. of observations	1970	1970	1970
F-statistic	66.7***	16.6***	15.5***
R-squared	0.1196	0.0327	0.0306
Adjusted r-sqd	0.1178	0.0308	0.0286

Notes: *, ** and *** represent statistical significance at 1%, 5% and 10% levels respectively. "Instrument 1" = Short-term internet risk, "Instrument 2" = Longer-term internet risk and "Instrument 3" = Internet quality risk.

The second estimation step of the CF method is to use the residuals from the three first stage equations to calculate the control function and introduce these as additional regressors in the utility model. Petrin and Train (2010) specify different ways in which the control functions (CF) enter the utility model. In this application the CFs enter the utility model without any transformation. That is, the control function is a parameter multiplied by each of the three residuals (Petrin and Train 2010).

However in order to further explore the unobserved preference heterogeneities in the sample seen above we employ the use of the mixed logit model described in chapter three. In our application, we assumed that the parameters on the three types of absolute risk reductions were random because it is questionable that everyone in the Albertan population has same preferences for absolute amounts of water outage risk reductions as depicted by the conventional models. We assumed a normal distribution for these random parameters and estimated the model in NLOGIT 5.0 using Halton draws (Halton 1960). Several authors have found that 100 Halton draws increases the accuracy of estimates more than 1000 independent random draws (Bhat 2001; Hensher 2001; Petrin and Train 2010). We also assume the triangular distribution for the random parameters as robustness checks.

Table 16 reports the results of mixed logit models before and after the application of the control function approach. The first column presents the results of the mixed logit model without endogeneity treatment. All the variables enter the model with signs that one would expect. The coefficient on the constant is positive and statistically significant at 1%, indicating a preference for the proposed alternative management program relative to the status quo. The coefficient on cost is also negative and statistically significant to signal that respondents are more likely to vote for the alternative program at lower costs. The respondents' responses to the valuation questions are not sensitive to the order of the questions as reflected by the insignificance of *order.*

The random parameter on short-risk reduction is positive and statistically significant at 1%. This indicates that overall the respondents are likely to vote for the alternative management program as the percentage of absolute short-term water outage risk reductions increases. The standard deviation of this random parameter is also statistically significant to indicate heterogeneous preference for short-term water outage risk reduction in the sample. Similarly the mean and standard deviation of the normally distributed random parameter on boil water advisory risk reduction are statistically significant. This means that respondents prefer higher percentages of boil water advisory reduction and the preferences are heterogeneous in the sample. However it appears that the preference for higher percentages of longer-term water outage risk reductions is not heterogeneous among the respondents.

The second column of Table 16 reports the results of the mixed logit models after attempts to correct for endogeneity using the control function approach. Again all the parameters have similar signs as the model with no endogeneity treatment. However the magnitudes of some of the parameters change after endogeneity treatment. For instance the coefficient on the constant increased from 0.5078 to 0.5662 after endogeneity treatment. This will have a significant impact on welfare measures as will be seen below.

The parameters of interest, which are the risk reduction variables, also change after endogeneity correction. The coefficient on absolute risk reduction of short-term water outage increases from 0.0076 to 0.0084. This can be explained by the significance of the residual introduced into the utility function to “control” endogeneity. This residual is negative and statistically significant to indicate that some unobserved variables may be reducing the magnitude of the impact of the absolute risk reductions of short-term water outage on the probability of a vote for the proposed alternative. However the residual from the longer-term water outage and boil water advisories are not statistically significant. The coefficients on these variables do not vary very much before or after endogeneity treatment. It is important to note that although these changes in parameters may appear small, they may have significant impacts when welfare measures are aggregated over the population.

Table 16 Estimates of mixed logit models before and after control function assuming a normal distribution for random parameters

	Model 14 (Non-control)	**Model 15 (Control function)**
	Coefficient (Std. Error)	Coefficient (Std. Error)
Constant	0.5078***	0.5662***
	(0.0855)	(0.1276)
Cost	-0.0086***	-0.0089***
	(0.0005)	(0.0005)
Short term risk		
Mean	0.0076***	0.0084***
	(0.0021)	(0.0022)
Variance	0.0858***	0.0873***
	(0.0050)	(0.0051)
Long term risk		
Mean	0.0044	0.0037
	(0.0063)	(0.0063)
Variance	0.0030	0.0006
	(0.0067)	(0.0068)
Boil water advisory		
Mean	0.0090*	0.0098**
	(0.0050)	(0.0047)
Variance	0.0139**	0.0215***
	(0.0055)	(0.0060)
Vote type	0.1596	0.1609
	(0.1097)	(0.1101)
Order	0.0573	0.0554
	(0.0839)	(0.0845)
Residual 1		-0.0127**
		(0.0061)
Residual 2		0.2071
		(0.2551)
Residual 3		-0.1217
		(0.2080)
No. of observations	1970	1970
Log likelihood	-1163.95	-1162.66
AIC	1.19	1.19

Notes: *, ** and *** represents statistical significance at 1%, 5% and 10% respectively. The standard errors of model 15 were computed using the bootstrap method and 10,000 draws.

As further robustness checks for our mixed logit models, we assumed a triangular distribution for the random parameters. Table 17 reports the results of the mixed logit estimates assuming triangular distribution for the random risk reduction parameters before and after endogeneity control. All the fixed parameters enter the non-control model with similar signs as before. The parameter on constant is positive to suggest preference for the alternative management program to reduce water outage risk perceptions relative to the status quo. The cost parameter is again negative and statistically significant to signal preference for the alternative program at lower costs. The responses to the valuation questions are not sensitive to sequencing effects as the *order* parameter is not statistically significant.

The three random parameters; the short-term risk reduction, the longer-term risk reduction and boil water advisory risk reduction, also have similar parameter signs and significance levels as the results from assuming normal distributions. The parameter on short-term risk is positive and statistically significant at 1% to indicate that the probability of vote in favour of the proposed alternative increases as the percentage risk reduction of short-term water outages increases. The standard deviation of this random parameter is statistically significant to signal preference heterogeneity in the sample. Just as in the model assuming a normal distribution, the parameter on long-term risk and its standard deviation are not statistically significant. However the boil water advisory random parameter is also statistically significant.

Both fixed and random parameters also have similar signs and significant levels after adding the residuals from the first stage equations to treat endogeneity. The residual from the short-term risk reduction is again statistically significant at 5% just as above. This indicates that the short-term risk reduction parameter is likely to be endogenous in our model. The endogeneity correction slightly increases the parameter magnitude of the short-term risk reduction variable from 0.0071 to 0.0079. The parameter on boil water advisory risk reduction also increases from 0.0091 to 0.0110 although its residual is not statistically significant. This could be explained by the use of the same instruments in the first stage equations. Again the results of the control function models indicate preference heterogeneity in the risk reduction level of short-term water outage and boil water advisory.

Table 17 Estimates of mixed logit models before and after control function assuming a triangular distribution for random parameters

	Model 16 (Non-control)	**Model 17 (Control function)**
	Coefficient (Std. Error)	Coefficient (Std. Error)
Constant	0.5096***	0.5689***
	(0.0855)	(0.1275)
Cost	-0.0086***	-0.0089***
	(0.0005)	(0.0005)
Short term risk		
Mean	0.0071***	0.0079***
	(0.0021)	(0.0022)
Variance	0.2001***	0.2044***
	(0.0118)	(0.0120)
Long term risk		
Mean	0.0045	0.0038
	(0.0063)	(0.0063)
Variance	0.0062	0.0014
	(0.0164)	(0.0167)
Boil water advisory		
Mean	0.0091**	0.0110**
	(0.0046)	(0.0048)
Variance	0.0381	0.0575***
	(0.0135)	(0.0146)
Vote type	0.1574	0.1582
	(0.1097)	(0.1101)
Order	0.0577	0.0559
	(0.0837)	(0.0843)
Residual 1		-0.0128**
		(0.0061)
Residual 2		0.1999
		(0.2548)
Residual 3		-0.1150
		(0.2078)
No. of observations	1970	1970
Log likelihood	-1164.52	-1163.19
AIC	1.19	1.19

Notes: *, ** and *** represents statistical significance at 1%, 5% and 10% respectively. The standard errors of model 15 were computed using the bootstrap method and 10,000 draws.

6.3 Welfare measures from all models

This section reports the results of willingness to pay (WTP) estimated using parameter estimates from the econometric models presented above. We first present the welfare measures from spike models that used all respondents in the survey data regardless of water reliability risk perceptions. WTP estimates from the random effects probit models, for only respondents with positive risk perceptions, using both exogenous and endogenous measures of water outage risk reductions are then presented. In addition the section reports WTP for mixed logit models before and after endogeneity control.

6.3.1 WTP measures from spike models

In the spike models the WTP for respondents with positive risk perceptions are weighted by the probability of positive WTP. This computation accounts for respondents with zero WTP because of a lack of perceived water reliability risks and therefore produces unconditional welfare measures. Hence the welfare measures presented here reflect the whole sample of respondents regardless of their water outage risk perceptions.

Table 18 reports the mean WTP computed from the parameter estimates of the spike models assuming three different distributions for WTP. The WTP estimates when both the logistic and normal distribution is assumed are similar. This can be explained by the symmetrical nature of both distributions (Haab and McConnell 2002). On the other hand the lognormal distribution likely overstates the WTP values because of its thick tail.

The spike model estimates indicate that households in Alberta regardless of their water risk perceptions are willing to pay between \$46 and \$49 for an alternative program that will reduce the risk of short-term water outages by more than 50% in the next 10 years. They are also willing to pay between \$54 and \$56 for a management program that will reduce their joint risks of short and longer-term water outages and boil water advisories. As discussed above these estimates are not sensitive to distributional assumptions about WTP except in the lognormal instance that has a considerably higher WTP.

Table 18 Mean Willingness to pay (WTP) ($ / household / year) from spike models for different distributional assumptions

Type of distribution assumption	Short-term risk reduction	Joint risk reduction of short-term, longer-term and BWA
Logistic CDF	$46.02	$55.56
	(2.54)	(2.70)
Normal CDF	$48.73	$54.55
	(1.54)	(1.50)
Lognormal CDF	$454.18	$688.51
	(102.64)	(159.75)

Notes: Standard errors of mean WTP are in parenthesis. These standard errors are computed using the Krinsky and Robb (Krinsky and Robb 1986) procedure and 1000 draws.

6.3.2 WTP from random effects probit models using exogenous risk reduction

Table 19 reports the mean WTP estimates calculated from the random effects probit model using the exogenous risk reduction for different portions of the sample. The results indicate that households expecting water outages are willing to pay about $71/year over the next 10 years in addition to their water bills for an alternative management program that will reduce their risk of short-term water outages by at least 50%.[24] Also these households are willing to pay about $99 per year in addition to their water bills for an alternative program that will reduce their joint risks of short-term outages, longer-term outages and boil water advisories by at least 50%.

Households who expect more than 20% annual chance of short-term water outages are willing to pay about $119 per year on their water bills for an alternative program that will reduce their short-term risk perceptions by 99%.[25] Such households are also willing to about $157 per year in addition to their water bills for an alternative management program that will reduce their joint risks of short and longer-term water outages and boil water advisories by 99% over the next 10 years.

[24] Welfare measures are not different for a 99% exogenous risk reduction. Respondents are therefore indifferent between a 50% or 99% exogenous risk reductions.

[25] Households in this group are willing to pay $65 per year for a 50% exogenous risk reduction of short-term water outages.

The welfare measures are also computed for different geographical locations of Alberta. Rural households that expect water outages in the next 10 years are willing to pay about $90 per year in addition to their water bills for alternative management programs that will reduce their risks of short-term water outages by at least 50%. Rural households are also willing to pay about $103 per year for alternative programs that will reduce their joint risk of short-term, longer-term and boil water advisories. On the other hand urban households in Alberta, that expect water outages, are willing to about $68 per year for a program that will reduce their risk of short-term water outage and $98 per year for programs that will reduce their joint risks.

Table 19 Mean willingness to pay (WTP) ($ / household / year) computed using parameter estimates from random effects probit models that used exogenous measures of risk reduction

	Short-term risk reduction	Joint risk reduction of short-term, longer-term and BWA
Full sample Mean WTP	$71.07	$98.99
	(10.65)	(10.60)
Respondents with >20 risk perceptions	$119.38	$156.88
	(24.88)	(25.69)
Rural Sample only	$89.84	$103.84
	(19.32)	(19.33)
Urban Sample only	$67.72	$98.11
	(13.26)	(13.05)

Notes: Standard errors of mean WTP are in parenthesis. These standard errors are computed using the Krinsky and Robb procedure (Krinsky and Robb 1986) and 1000 draws. BWA means "boil water advisory". "Full sample" in this context is only respondents with positive risk perceptions.

6.3.3 WTP from random effects probit models using endogenous absolute risk reduction

Table 20 presents the marginal WTP for the endogenous levels of risk reduction as well the overall mean WTP evaluated at mean percentage of water outage risk reductions. The results indicate that the respondents are willing to pay about 85 cents for a percentage reduction in their risk of boil water advisories. The mean WTP for these respondents for a program that will reduce their risks of short-term and longer-term water outages and boil water advisories, evaluated at the mean percentage risk reduction of boil water advisories, is about $95 per year over the next 10 years.[26]

Marginal WTP for significant program attributes are also computed for rural and urban households of Alberta. The results indicate that rural community households expecting short-term water outages are willing to pay an additional 90 cents per percentage risk reduction of short-term water outages. The mean WTP for a program that will reduce their risks of water outages, evaluated at mean percentage short-term risk reduction, is about $59 per year for the next 10 years. Finally urban community households that expect boil water advisories are willing to pay about 96 cents for a percentage risk reduction of boil water advisories.

Table 20 Marginal and mean WTP ($ / household / year) computed using parameter estimates from random effects probit models that used endogenous absolute measures of risk reduction

	MWTP for short-term risk reduction	MWTP for longer-term risk reduction	MWTP for BWA risk reduction	Mean WTP
Full Sample	Not sig	Not sig	$0.85 (0.49)	$94.07 (10.67)
Rural sample	$0.90 (0.47)	Not sig	Not sig	$59.22 (19.27)
Urban Sample	Not sig	Not sig	$0.96 (0.58)	$96.95 (12.99)

Notes: Standard errors of mean WTP are in parenthesis. These standard errors are computed using the Krinsky and Robb procedure and 1000 draws. MWTP means marginal willingness to pay. "Not sig" means the marginal WTP values are not statistically different from zero and are therefore not reported. "Full sample" in this context is only respondents with positive risk perceptions.

[26] In calculating this estimate, the boil water advisory reduction coefficient is multiplied by the average boil water advisory risk reduction. The result is added to the coefficient on the constant and divided by the bid coefficient.

6.3.4 WTP estimates from mixed logit models that account for endogeneity

Table 21 reports the WTP estimates from the mixed logit models that attempted to treat the endogeneity of the risk perceptions. The WTP measures are not different for any of the distributional assumptions for the random parameters. The WTP per percentage of short-term water outage risk reduction increases from about 88 cents to 93 cents after endogeneity control. The marginal WTP for a percentage increase in the reduction of boil water advisories also increases from $1.05 to about $1.10 after endogeneity control.

Similarly, the mean WTP for the alternative program that will reduce the risks of short-term water outage, evaluated at the mean short-term risk reduction, increases from about $79 per year to about $85 after endogeneity control. The mean WTP for a joint risk reduction of short-term, longer-term water outages and boil water advisories, evaluated at the mean percentage risk reduction of short-term outages and boil water advisories, increases from about $102 per year to about $107.65 per year after endogeneity control. This increase in WTP estimate could be attributed to the underestimation of coefficient on short-term risk reduction because of omitted unobserved variables.

These increases in the welfare measures after endogeneity control, relative to the unadjusted estimates, appear to be small. They can however not be neglected as these welfare measures will be aggregated over the Albertan population. Ignoring these differences in estimates may underestimate the overall economic value of drinking water reliability in Alberta.

Table 21 Willingness to pay (WTP) ($ / household / year) estimates for control and non-control mixed logit models assuming normal distribution and triangular for random parameters

	MWTP for short-term risk reduction	MWTP for longer-term risk reduction	MWTP for BWA risk reduction	Mean WTP (Short-term risk)	Mean WTP (Joint risk)
Normal distribution (non-control)	$0.88 (0.24)	Not sig	$1.05 (0.54)	$79.35 (8.00)	$102.66 (9.33)
Normal distribution (control)	$0.93 (0.24)	Not sig	$1.10 (0.53)	$85.00 (14.18)	$107.65 (14.95)
Triangular distribution (non-control)	$0.83 (0.25)	Not sig	$1.07 (0.53)	$78.61 (8.05)	$101.84 (9.81)
Triangular distribution (control)	$0.89 (0.26)	Not sig	$1.14 (0.52)	$84.11 (13.82)	$107.00 (15.07)

Notes: Standard errors of mean WTP are in parenthesis. These standard errors are computed using the Krinsky and Robb procedure and 1000 draws. MWTP means marginal willingness to pay.

6.4 Aggregation of welfare measures

The WTP estimates presented above are at the household level. Since the overall objective of this study is to provide an estimate of the economic value of drinking water reliability in Alberta, these welfare measures can be aggregated over the number of households in Alberta. The 2011 Canada census indicated that there were about 1,390,275 private households in Alberta (Statistics Canada 2011). Multiplying this by the household estimates of the value of water reliability in Alberta yields the annual benefit of water reliability risk reducing programs. Using the household WTP estimates from the random effects probit models that used exogenous risk reductions ($71 per household per year), we calculate an economic value of about $98.7m per year for a more than 50% risk reduction of short-term water outages. This value reduces to about $64.0m per year when we use household estimates from spike models that account for the entire population.

The mixed logit model estimates can also be used to calculate aggregate welfare measures. For instance using the estimates from mixed logit models without endogeneity control yields an economic value of $110.3m per year. With endogeneity control this value increases to about $118.2m per year. Neglecting the endogeneity of the risk reduction variables would have led to underestimating the value of water reliability in Alberta by about $8m or about seven percent.

The economic value of drinking water reliability can also be estimated for different municipalities in Alberta. For instance, Edmonton has about 450,785 households (Statistics Canada 2011). These numbers imply that the economic value for a 50% risk reduction of water reliability challenges in Edmonton is about $32 million per year. Again using the estimates from the spike models reduces this value to about $20.7m per year.

6.5 Chapter summary

This chapter has presented frequency of responses to the valuation questions as well parametric analysis of these responses. Random effects models using exogenous levels of water outage risk reduction show overall preference for alternative management programs that will reduce the risk of water reliability challenges in the future relative to the status quo. The likelihood of supporting such programs declines as the cost of the alternative programs increases as one would expect. Sensitivity to scope tests indicates insensitivity to scope in the entire sample. However the value of water reliability risk reducing programs is sensitive to scope when respondents with small risk perceptions are removed from the sample.

Welfare measures from random effects probit models using only respondents with positive water outage risk perceptions reduce when the econometric models are expanded to include all respondents regardless of their risk perceptions. Results from control function models show that, given our instruments, short-term water risk reduction measures are endogenous in our model. This endogeneity leads to small increases in the marginal WTP for short-term risk reductions. Although these changes appear small at the household level, they become large when welfare measures are aggregated over the entire Alberta population.

CHAPTER SEVEN: SUMMARY AND POLICY IMPLICATIONS

7.0 Summary

The overall objective of this study was to provide an estimate of the value of drinking water reliability. This value can be used to monetize the benefits of forest and watershed management practices as a method of improving drinking water reliability in Alberta. This monetary benefit can then be compared with the costs associated with the adoption of forest and watershed management practices to improve drinking water reliability in Alberta. This approach will help inform investment decisions into "green" infrastructure or traditional water treatment infrastructure ("grey" infrastructure) and can be used to assess differences between these measures if there are public preferences associated with one or the other.

The objective of the study was achieved by employing stated preference methods because the value of water resources is difficult to observe in practice. An initial survey was constructed and tested using respondents that participated in focus groups in different parts of Alberta in the spring of 2014. The survey was modified after the focus groups and again tested through a pilot survey of 155 Albertans between January and February of 2015. The final survey was administered by an Edmonton-based survey research firm. A total of 1250 responses were valid for analysis.

The survey collected information on respondents' experiences with short-term water outages, longer-term water outages and boil water advisories, in the last 10 years. Analysis of these numerical amounts indicates that 65% of the respondents did not experience any short-term water outages in the last 10 years. On average, respondents experienced 1 short-term water outage in the last 10 years. About 80% of the respondents did not experience longer-term outages or boil water advisories in the last 10 years. These results testify to the current reliability of drinking water in Alberta.

Information on respondents' future numerical risk perceptions of water outages was collected as part of the survey. These results indicate that about 78% of the respondents expect short-term water outages in the next 10 years despite experiencing few of such outages in the last 10 years. Similarly, about 55% of the respondents expect longer-term water outages and boil water advisories in the next 10 years.

Survey respondents were also presented with a contingent valuation question and a hybrid valuation question based on their risk perceptions of water outages. In the CV question, the respondents were presented with an alternative management program that will reduce their risk perceptions of short-term water outages by either 50% or 99%, but will lead to an increase in their water bills by a stated amount of money. They were asked to choose between this alternative management program and the status quo. In the hybrid valuation question respondents were presented with an alternative program that will reduce their risk perceptions of short-term water outages, longer-term water outages and boil water advisories to either 50% or 99%, but at a stated cost. They were asked to choose between this alternative and the status quo.

Frequency of responses in favour of the proposed management alternative in both valuation questions indicated support for the proposed alternative. However, the likelihood of support for the programs declines when the cost of the programs increases as one would expect. These responses were also compared for different community sizes to examine any observed preference heterogeneities. The results indicate little preference heterogeneity for programs that will reduce risks of different water outages in different community sizes.

A joint parametric analysis of both votes was performed. This joint analysis helped increased the number of observations per respondent and therefore the robustness of models estimated. The two valuation questions were presented to respondents with positive risk of water outages. About 21% of the respondents did not receive any of the valuation questions because of a lack perceived risk of water outages. Implicitly, this group of respondents have zero WTP. Kristrom's simple spike model was adopted to account for the presence of such respondents in the data. Different distributional assumptions were made about the WTP. Parameter estimates from the normal, logistic and lognormal CDFs had similar signs and statistical significance. The overall sample support programs that will reduce risks of water outages, but the likelihood of support reduces as the costs of the program increase. Using these parameter estimates we calculated a mean WTP of $46 per year for both the logistic and normal distributions. The lognormal distribution overestimated the mean WTP.

The results of random effects probit models using exogenous measures of risk reduction indicated that respondents, who expect water outages, prefer the alternative management program relative to the status quo. They also prefer these programs at lower costs. Because the voting order was randomized a test of order effects in the responses was performed. The results indicated that generally the responses to the valuation questions are insensitive to the order in which the questions are presented. Tests of scope sensitivity of the valuation respondents indicated insensitivity for the whole sample. However the valuation is sensitive to scope when respondents with less than 20% risk reduction are removed from the sample. This could be explained by the fact that respondents may be insensitive to higher or lower risk reductions because of low risk perceptions. Using the parameter estimates of this model, we calculated a mean WTP of $71 per year for an alternative program that will reduce the risk of short-term water outages by at least 50%. Similarly respondents are willing to pay $99 per year for a management program that will reduce their joint risks of short-term water outages, longer-term water outages, and boil water advisories by at least 50%. Models were also estimated for rural and urban sample of respondents.

Absolute risk reductions were also computed based on the respondents' risk perceptions and included in various econometric models. However we suspected that these measures may be endogenous in the econometric models. The control function approach was used in an attempt to correct this endogeneity following Petrin and Train (2010). This approach required valid instruments. We chose the respondents risk perceptions of internet service outages as instruments. Correlation matrices of these internet risk perceptions and the endogenous measures of risk perceptions indicated strong correlation. In order to further explore preference heterogeneities in the sample of respondents with positive risk perceptions, the mixed logit model was used in the second stage of the control function approach. Parameter estimates of mixed logit models before endogeneity control indicated that cost of the program, the absolute risk reduction of short-term water outages, and the absolute risk reduction of boil water advisories influence the probability of vote in favour of the proposed alternative program. The results also indicate that preference for short-term and boil water advisory risk reductions are heterogeneous in the sample. The results of the control function mixed logit models showed that, given our selected instruments, the absolute short-term risk reductions were endogenous in our models. Correcting the endogeneity slightly increased the coefficient of this variable. Marginal WTP for short-term risk reductions increased from $0.88 to $0.93 per percentage after endogeneity control. Mean WTP for a short-term risk reduction, evaluated at the mean percentage short-term risk reduction, also increased from $79 per year to $85 per year after endogeneity control. Although these increases appear small they have higher impacts when welfare measures are aggregated over the number of households in Alberta. Neglecting the endogeneity of the short-term risk reduction underestimated the value of water reliability in Alberta by $8m per year.

7.1 Policy implications of results

This study has provided information on Albertans' experiences of, and future risk perceptions of, different types of water outages. This information can be used by water utility service providers to assess the quality of service they provide for customers. On one hand, these customers have experienced few water outages which are a testament to the current reliability of water in Alberta. On the other hand, these customers expect significant percentages of water outages in the future which call for substantive investments to remedy.

The study has also provided many estimates of the economic value of drinking water reliability in Alberta. Policy makers at water utility providers can compare these estimates with the costs they will incur in implementing forest and watershed management. This will then inform their investment decisions in order to improve the reliability of drinking in the future.

Household estimates for water reliability risk reducing programs have also been provided in this study. These estimates can be used to construct efficient water management and pricing schemes in order to improve reduce the risks of water outages. In other words, these estimates give water utility service information on how much extra to charge households per month (or year) in order for them to avoid adverse outcomes associated with water outages.

Finally, if supported by economic analysis of costs and benefits and water utility providers decide to adopt forest and watershed management, they can partner with forest authorities following the same application of such framework in Denver. Forest authorities can management watersheds that are critical to Alberta's water supply, using these funds.

7.2 Study limitations and directions for future research

There are a number of limitations of this study that must be taken into account when interpreting the findings. The first set of limitations relate to the data used for this study. The data are from an online survey that used an opt-in panel. Although the survey results indicate some representativeness of the sample in terms of observable characteristics, people differ by unobservable characteristics. The data from an opt-in panel may therefore not be representative of the Alberta population. Furthermore the use of an opt-in panel could result in sample selection bias. We also did not have information on the number of potential respondents that refused to answer the survey. There could therefore be inconsistencies in the parameter estimates of our regression models and uncertainty regarding the aggregation of household willingness to pay estimates to the Albertan population. For instance it is unclear whether non-respondents have a zero WTP or the average sample WTP.

The next set of limitation is sensitivity analyses around the analysis of stated preference questions. Many different methods of assessing the validity of stated preference responses have been used in the literature. First, the econometric models do not account for uncertainty of responses to the valuation questions. This could have led to an overestimation of the "true" monetary value of drinking water reliability in Alberta. This is because respondents who voted in favour of the proposed programs, but are uncertain of how they will vote in an actual referendum, may vote against the programs in an actual referendum. The study did not attempt to account for uncertainty of responses in the econometric models because many specifications were already being examined and it was unclear whether accounting for uncertainty would provide additional insights into the issue.

Second, the study also did not attempt to remove protest responses in the estimation of welfare measures. Protest votes are not uncommon in stated preference studies. Not excluding them from the analysis can be a threat to the validity and reliability of estimates from the study. However, identifying protest responses in discrete choice data is difficult. Although the survey included questions that can be used to partly identify protest responses, the study did not account for such responses in computing welfare measures. These responses however may not reflect “true” economic values (Jorgensen et al. 1999) and therefore future research must take steps to account for protest responses in the econometric model estimation.

The study also did not perform consequentiality tests to reveal any differences between respondents who believed that their responses could influence policy decisions and those who do not. Survey respondents have different incentives to respond truthfully to questions. According to Carson and Groves (2007), survey respondents will answer truthfully to a question under two conditions; first, when they believe that their responses will influence the account they like (i.e. policy consequentiality) and two, when there is some perceived probability that they will have to pay the bid amounts in the survey (payment consequentiality). The survey included some questions that can be used for policy consequentiality tests and can be used in future research. However no questions on payment consequentiality were included. For these reasons and that further analysis would create additional complications in the interpretation of results, the analysis of consequentiality tests was not conducted. However, this is an avenue for future research.

Also, the study employed stated preference methods to elicit households' willingness to pay for reliability improvement. There are a number of issues regarding the usage of SP methods. Chief among these issues is strategic behaviour because of the hypothetical nature of the task. Although the study used various methods to address this, there may be room for improvements. Future studies can attempt to do revealed preference analysis since those are based on observed behaviour and may reflect “real” preferences.

Finally, the study used internet service outages as instruments for controlling endogeneity of water outage risk reductions. These instruments were not very strong as the correlations between them and the potentially endogenous variables were not very high. Future research looking to further explore the endogeneity of water outage risk perceptions using the control function approach could consider using electricity outages as instruments as both water and electricity are more complementary utilities.

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APPENDICES

Appendix A: Full survey instrument

Water Management in Cities and Towns

A research project to support policy making and decision making. Sponsored by the Water Economics Policy and Governance Research Network. Conducted by researchers from the University of Alberta and Brock University.

Study Overview

Water Management in Cities and Towns

Principal Investigators:
Vic Adamowicz, Professor at University of Alberta, Department of Resource Economics and Environmental Sociology; Phone: 780-492-4603

Pat Lloyd-Smith, Graduate Student at University of Alberta, Department of Resource Economics and Environmental Sociology; and

Diane Dupont, Professor at Brock University; Department of Economics

James Price, Post-Doctoral Fellow, Brock University, Department of Economics

Diane.dupont@brocku.ca; vic.adamowicz@ualberta.ca; lloydsmi@ualberta.ca; jprice@brocku.ca

You are invited to participate in a study on water management that involves researchers in Alberta and Ontario.

Who is funding this? This study is being funded by the Water Economics, Policy and Governance Network, a network of Canadian researchers who have joined together to look at water issues, and the Canadian Water Network, a multidisciplinary water research and knowledge mobilization network.

Partners in this project include Alberta Environment and Sustainable Resource Development and the Canadian Forest Service.

[PROGRAMMER NOTE: Split sample on inclusion of partner funding note above]

What is the Purpose? The goal of this research is to determine public preferences for improved water management and quality and to avoid adverse outcomes associated with drinking water supply.

What Methods are Being Used? We are asking you to take part in a survey being held across Alberta. This information could be used to structure more efficient water management and pricing schemes for municipal water utilities and to aid these utilities in their infrastructure investment decisions. The survey should take about 25 minutes of your time.

What are the Benefits to You? Survey participants will assist the researchers in obtaining estimates of the public's perceptions of water supplies and quality and the importance of clean and reliable water for Albertans. There are no known or anticipated risks associated with participation in this study.

Confidentiality: All information you provide is considered confidential and grouped with responses from other participants. Names will not be associated with survey responses. Access to the data will be restricted to investigators.

Withdrawal: Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study. Further, you may decide to withdraw from this study at any time and may do so without any penalty or loss of benefits to which you are entitled. Once the survey has been completed you cannot withdraw the information you provided.

Publication of Results: Grouped results of this study may be published in professional journals and presented at conferences as well as in the graduate student's thesis. Feedback about this study will be available December 2015 from the principal investigators using the contact information provided above.

Contact Information and Ethics Clearance: If you have any questions about this study or require further information, please contact the Principal Investigators using the contact information provided below. This study has been reviewed and received ethics clearance through the Research Ethics Board at the University of Alberta (file #Pro00051054) and through the Research Ethics Board at Brock University (File #14-040). For questions regarding participant rights and ethical conduct of research, contact the University of Alberta's Research Ethics Office at (780) 492-2615. Thank you for your assistance in this research project.

Contact for Further Information: Vic Adamowicz, University of Alberta, Department of Resource Economics and Environmental Sociology; Phone: 780-492-4603; Email: Vic.Adamowicz@ualberta.ca

1. Approximately how many people live in your current community (city, town or village)?

___Fewer than 15,000
___Between 15,000 and 100,000
___More than 100,000

2. How long have you lived in your current community (city, town or village)?

______ YEARS

3. Before moving to your current community, where were you living before?

______ I have always lived in my current community
______ A similar sized community in Alberta
______ A smaller sized community in Alberta
______ A larger sized community in Alberta
______ A community outside of Alberta

4. How long do you plan to live in your current community? Please select one timeframe.

______ 0- 5 years
______ 6-10 years
______ More than 10 years

We would like to know your views on various options for investing public funds. What follows is a list of government programs that are partially paid for by your taxes.

5. In your opinion, how important is it for your municipal government to invest in each of the following? Please use a scale of 1 to 5 where **1** means **not at all important** and **5** means **very important**.

Please select one response for each item

1 – Not at all important
2
3
4
5 – Very important

Policing services
Food/restaurant safety services

Poverty and social assistance programs
Schools and education
Environmental protection
Clean, reliable water supply
Transportation infrastructure (e.g. roads, bridges)

6. Using a scale of 1 to 5 where **1** means **strongly disagree** and **5** means **strongly agree**, please indicate your agreement or disagreement with the following statements regarding environment and development goals.

Please select one response for each item
1 – Strongly disagree
2
3
4
5 – Strongly agree

Environmental improvement programs that would be harmful to business should not be carried out
Environmental improvements are fine as long as taxes do not increase
Experts should solve environmental issues and the public should only be educated and informed of the decisions
New technology will solve most environmental problems
In the future, humans will be able to understand and control most natural processes.
Human progress is limited only by technology and not by the environment

We now want to ask you a few questions about water in your home and community.

7. Are you on a city/municipal water system?

_____ YES
_____ NO
_____ Don’t Know

If YES, do you pay a water bill?

_____ YES
_____ NO

There are three sources of <u>drinking water used in the home</u> that we want you to think about:

(i) Tap water (either from a well or a municipal source)
(ii) In-home Treated Tap Water (In-home filtration using a tap attachment, container style filtration system, refrigerator attachment or boiling)

(iii) Purchased bottled water (water bottles of any size, purchased from a grocery store or a home delivery service, such as Culligan, Alberta Fresh Springs, Water Pure & Simple, etc.)

8. For the three water sources, please indicate the percentage of water you personally consume <u>at home</u> that comes from each source in any given month. If your answer is zero in any category you must enter 0%.

Water Type	% Consumed
Tap water	
In-home Treated/Filtered Tap Water	
Purchased water (bottled or from home delivery)	
Total (100%)	100%

Water Quality
Now we would like to collect some information from you about the quality of your regular water supply.

9. Which, if any, of the following have you experienced with the tap water in your home over the past year? Please select all that apply.

_____ Rusty colour
_____ Sediment (particles at the bottom of a glass)
_____ Unpleasant smell (e.g., musty, chlorine)
_____ Unpleasant taste (e.g., musty, chlorine)
_____ Hard water / mineral deposits
_____ Pollutants or other contamination
_____ Low water flow/insufficient water pressure
_____ Other _______________________________
_____ None of the above

10. Looking forward five years, do you expect the quality of your tap water at home to be...? Please select one response only.

_____ Worse than today
_____ Same as today
_____ Better than today
_____ Don't know

11. Which of the following statements best reflects your personal opinion about health concerns you might have with the tap water in your home? Please select one response only.

______ Drinking tap water does not pose a problem for my health or my family's health
______ Drinking tap water poses a minor problem for my health or my family's health
______ Drinking tap water poses a moderate problem for my health or my family's health
______ Drinking tap water poses a serious problem for my health or my family's health

12. Comparing health effects from drinking bottled water (purchased water) to health effects from drinking your home's tap water, do you think that bottled water is…? Please select one.

______ Much more safe than tap water
______ A little safer than tap water
______ About as safe as tap water
______ A little less safe than tap water
______ Much less safe than tap water
______ Don't know/Not sure

13. To the best of your knowledge, have you or anyone in your household ever become sick from drinking any of the following types of water in your home? Select one from each row.

	Yes	No	Don't Know
Tap water			
In-home treated tap water (filtered water)			
Purchased bottled water			

14. For each of the following items that might be present in a household's tap water, please indicate if you have heard about it as a concern with drinking tap water and if any of these items has been a special concern in your community. Please select all that apply for each column.

	Heard About it as a Drinking Water Concern	Drinking Water Concern in My Community	Have not heard about is as a Drinking Water Concern
Microbe – E. coli			

Microbe – Cryptosporidium			
Microbe – Giardia (Beaver Fever)			
Chemical – Fluoride			
Chemical – Trihalomethanes			
Metals – Iron, Lead, Mercury			
Chemical – Pesticides			
Chemical - Pharmaceuticals			

15. Considering each of these contaminants, how much of a health concern do you personally believe each poses in your home's tap water? Please select one for each row.

	No Health Concern	Minor Health Concern	Moderate Health Concern	Serious Health Concern	Don't Know/Uncertain
Microbe – E. coli					
Microbe – Cryptosporidium					
Microbe – Giardia (Beaver Fever)					
Chemical – Fluoride					
Chemical – Trihalomethanes					
Metals – Iron, Lead, Mercury					
Chemical – Pesticides					
Chemical - Pharmaceuticals					

Water Reliability
The remainder of the survey will deal with water reliability issues. Water reliability refers to good quality water being available at any time of day without interruptions**.**

16. Have you experienced any loss of service to the tap water **in your home** in the past year? This can be either a planned or unplanned interruption in water availability or service. Please select all that apply.

_____ Tap water was unavailable (cut off) for some period of time
_____ Boil water advisory was issued
_____ We were unable to obtain tap water for other reasons (e.g. plumbing work in the neighborhood or home, etc.)
_____ We didn't drink the tap water because of smells, colour or some other reason – even though there wasn't an official advisory
_____ There was a water use restriction like a lawn watering restriction or some other public restriction or advisory asking for reduced water use.
_____ We have not experienced any loss of service to our tap water in the past year

17. How much of an inconvenience have water outages like the ones described in the previous question been for you? (please select one category)
_____ No inconvenience
_____ Minor inconvenience
_____ Moderate inconvenience
_____ Significant inconvenience

18. Do you keep any "back up" sources of water on hand, specifically so that you will have potable water in the event of a reliability problem with your tap water supply (for example, when there is a boil water advisory or a water outage)?

YES _____
NO _____

Some people keep "back up" sources of water on hand, specifically so that they will have potable water in the event of a reliability problem with their tap water supply (for example, when there is a boil water advisory or a water outage).

19. Please indicate which sources of "back up" water you keep on hand (check all that apply).

If you do not keep "back up" sources of water on hand, please select the final option from the list below.

_____ Bottles of water (e.g. a case of small bottles kept specifically for outages)
_____ Water containers (e.g. a large water container kept specifically for outages)
_____ Equipment for boiling large quantities of water
_____ An in-home water treatment system
_____ Individual water purification system (i.e. Katadyn, LifeStraw)
_____ Rain barrels or other outdoor storage systems
_____ Other water supply alternatives (please specify):__________________
_____ Do not keep "back up" sources of water on hand

20. Approximately how much do spend on these “back up” sources of water (i.e. specifically for water outages) in a year?

$________

21. Looking back over the last 10 years, how many times have the following types of water outage (loss of service) events occurred? For example, if you think you have consistently had about one boil water advisory every 2 years, then this would be 5 events in total over 10 years.

Water Outage Event	Number of events over last 10 years
Expected Water Outage	
Planned water outage (i.e. notice given in advance that tap water will be unavailable for a certain amount of time in the future)	____ events
Unexpected Water Outages	
Short-term unexpected water outage **lasting a few hours but less than a day**	____ events
Longer-term unexpected water outage **lasting at least 1-2 days**	____ events
Boil water advisory	____ events
No official advisory, but we didn’t drink tap water because of smells, colour, or some other reason	____ events

22. Looking forward 10 years and based on your experience and understanding of water management in your community, do you think the number of water outages events will

_____ Increase
_____ Stay the same

_____ Decrease
_____ Don't know/Not sure

23. We are now interested in understanding your expectations in terms of annual percent chances of three specific water outage events occurring over the next 10 years. The following table illustrates the relationship between the number of expected events over the next 10 years and the annual percent chance. Note that if you expect more than ten events of a specific water outage type over the next 10 years, the annual percent chance is still expressed as 100%.

Approximate number of events over next 10 years	Annual percent chance of water outage event over next 10 years
0 in 10 years	0%
1 in 10 years	10%
2 in 10 years	20%
…	…
9 in 10 years	90%
10+ in 10 years	100%

24. To ensure that we have communicated the idea of percent of water outages we would like you to answer the following question.

    Suppose you are given the choice of living in one of two communities that are identical except for their annual percent chance of a water outage. Community **A** faces 2 water outages in 10 years, whereas community **B** has a 30% annual chance of water outage over the next 10 years. Which community would you choose to live in? *Please select one response only.*

    ____Community A: 2 water outages in 10 years
    ____Community B: 30% annual chance of water outage over the next 10 years.

"You answered community B, but that community will have 3 water outages in a ten year period, which is more than community A. The 30% annual chance of water outage means that there will be about 3 outages in 10 years."

25. Looking forward 10 years and based on your experience and understanding of water management in your community, what would be your best guess of the annual percent chance that you (your household) will experience the following water outage events. *Please write your response between 0 and 100 in the following table*

Water Outage Event	Annual Percent Chance of Water Outage Event over next 10 years (0-100%)
24a: A short-term unexpected water outage **lasting a couple of hours**	____%
24b: A longer-term unexpected water outage **lasting at least 1-2 days**	____%
24c: A boil water advisory	____%

26. How confident are you of your responses in the previous question? For each level, please select one response only using a scale from 1 to 5, where 1 is not confident and 5 is confident.

Confidence of expectations	Not Confident		Somewhat Confident		Confident
A short-term unexpected water outage **lasting a few hours but less than a day**	1	2	3	4	5
A longer-term unexpected water outage **lasting at least 1-2 days**	1	2	3	4	5
A boil water advisory	1	2	3	4	5

27. Suppose that you received a letter telling you to expect two water supply interruptions to occur without warning over the next 12 months. You could expect each of these interruptions to be repaired within 1 to 2 days. What action would you take?

Please choose one of the options below.

_____ Take no action to prepare for an interruption (no cost to you)

_____ Spend about $5 buying bottled water to keep in the house

_____ Spend about $35 buying a 25-litre water container to keep in the house

_____ Spend about $70 buying two 25-litre water containers to keep in the house

_____ Spend about $105 buying three 25-litre water containers to keep in the house.

Internet Service Outages
The following two questions consider at-home *internet service outages and/or interruptions.* We are interested in comparing your experiences with internet outages to your experiences with water outages.

28. Have you experienced any loss of *internet* services in the past 5 years? This can be either a planned or unplanned interruption in internet service. Please select all that apply.

______ The internet was out for some period of time because of an unexpected event (i.e. technical issues, storm)
______ The internet was not available because of a planned interruption and the internet company provided advance notice (i.e. system upgrade in local area)
______ I have not experienced a loss of internet service in the past 5 years

29. Looking forward 5 years and based on your experience of *internet services* in your community, what would be your best guess of the annual percent chance that you (your household) will experience at least 1 of the following events? *Please write your response in the following table.*

Remember to treat each internet outage event independently (i.e., please enter a response between 0 and 100 for each row in the following table).

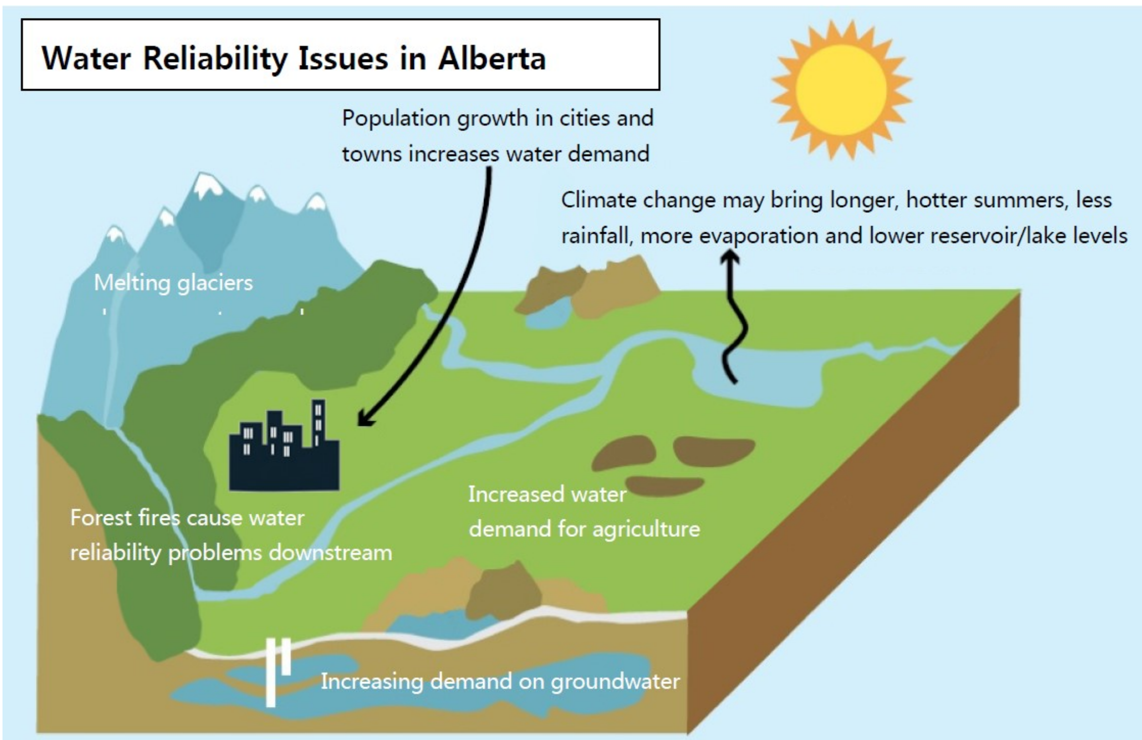
Internet Outage Event	Annual Percent Chance of Internet Outage Event over next 5 years (0-100%)
A short-term unexpected internet outage **lasting a few hours but less than a day**	____%
A longer-term unexpected internet outage **lasting at least 1-2 days**	____%
A series of unexpected outages that come and go sporadically and last minutes rather than hours (i.e., a patchy connection)	____%

THE FUTURE OF DRINKING WATER IN ALBERTA

We would like to turn your attention back to drinking water reliability in Alberta.

Over the last few years many parts of Alberta have experienced water shortages, unplanned outages or boil water advisories. Scientists are concerned that summer droughts will become more frequent and severe in Alberta leading to an increase in the frequency / severity of water shortages. Click here for a graphic illustrating some of the potential water supply and demand issues in the province.

[GRAPHIC FOR HOVERLINK]



Source: Adapted from Prairie Adaptation Research Collaborative (http://www.parc.ca/research_projects-ssrb.htm)

Another water reliability concern relates to forest fires. The vast majority of Alberta's drinking water originates from the forested slopes of the Rocky Mountains. A recent scientific study in southwestern Alberta has documented the effects of forest fires on water quality and the potential for negative downstream impacts on drinking water treatment systems (Emelko et al., 2011). These negative impacts might lead to water outages for communities.

30. Are you concerned that summer droughts will become more frequent and severe in Alberta?

_____ Yes
_____ No
_____ Don't know

31. Are you concerned that forest fires will become more frequent and severe in Alberta?

_____ Yes
_____ No
_____ Don't know

Other communities in North America, such as Denver, Colorado, have experienced water reliability problems from droughts and forest fires and have identified various ways to reduce the impact of these events on water reliability. Denver recently implemented additional water fees on households to modify forest vegetation and improve water reliability (click here for more info). These preventative measures might include increasing the capacity of the water treatment plant or modifying the equipment in the plant. Other actions such as forest management to reduce fire risks might be taken to reduce the chances of water outages. However, these measures and actions might result in higher water treatment costs and water bills to residential consumers.

In the following sections we ask you to consider which measures and actions you think would be valuable as ways to reduce the chance of water outages.

Water Reliability in Cities and Towns

We are going to present you with different water reliability programs and ask you to choose your preferred program as if you were voting in a referendum. You will vote up to three times and please treat each vote independently for each question. Note that while the questions focus on municipal drinking water management options, industry and other water users would also pay their fair share of any program costs.

We know that how people vote in surveys is often not a reliable indication of how people will actually vote. In surveys some people ignore the sacrifices they would need to make if their vote actually meant they would have less money to spend. In a recent survey like this one, 55% of the people in a community voted for a new program. When the program was put to a vote for real, only 40% actually voted for the program. Therefore, we'd like you to vote in this survey as if your vote was real -- imagine that you actually will have to dig into your pocket and pay the additional charges on your household's water bill if the majority agreed to go ahead with a program.

Some people might choose to vote to keep the current situation because they think:

- It is too much money for the type of benefit I expect to receive.
- The community's tap water supply is reliable enough.
- There are other places where my money would be better spent.

Other people might choose one of the management options because they think:

- The benefits in terms of making water supplies reliable are worth the money.
- This is a good use of money compared to other things I can spend my money on.
- The community tap water isn't very reliable so this would be a good investment.

Managing Your Community's Future Water Supply

We are going to ask you to vote on two different management programs relating to the future of your community's water supply.

The Future of Water In Your Community: Vote One

Suppose that you had a choice between the current situation and a proposed program in a referendum on water reliability.

Current situation: You have indicated that you expect that in a community such as yours there will be about a ____% (transfer responses from Question 24a within program) chance of an unexpected short term (a couple of hours) water outage or reliability problem each year over the next 10 years.

Proposed Management Program: With new investments in management of the water treatment facilities and the watershed, it is estimated that the water outages or reliability problems in your community could be reduced by half to a __________% (divide response from Q24a by 2 and put value in here) chance of a short term water outage or reliability problem each year over the next 10 years.

[OR ALTERNATE OPTION]…could be reduced almost entirely to a less than 1% chance of a short-term water outage or reliability problem each year over the next 10 years.

32. If your community holds a referendum to determine whether to put into place the Proposed Management Program and you are asked to vote for or against the program, what would you choose?

Please read the following two statements and choose the one that indicates how you would vote. If you are not currently paying your own water bill, please consider these amounts as increases to your monthly rent (as it is common that rent includes payments for water).

___Yes, I am willing to pay $___ more on my water bill every month ($__ per year) for 10 years starting in January 2015 to pay for the Proposed Management Program that reduces the chance of a short term water outage from ____% (transfer responses from Question 24a within program) by half to a _____________% (divide response from Q24a by 2 and put value in here) chance of an outage each year over the next 10 years.

OR ALTERNATE OPTION…could be reduced almost entirely to a less than 1% chance of a short term water outage or reliability problem each year over the next 10 years.

___No, I am not willing to pay $___ more on my water bill every month ($__ per year) for 10 years starting in January 2015 to pay for the Proposed Management Program.

33. On a scale from 1 to 5, where 1 is uncertain and 5 is certain, how certain are you that this is the option you would choose if this was an actual vote. Please select one response only.

Uncertain		Somewhat Certain		Certain
1	2	3	4	5

34. To what extent do you believe that the voting results collected from you and other survey respondents will be taken into consideration by policy makers?

Not taken into account				Definitely taken into account
1	2	3	4	5

35. What do you think a person like you in your community (i.e. similar demographics, life situation) would choose in a referendum like the one just described?
_____ They would vote Yes to the proposed management program
_____ They would vote No to the proposed management program

36. What do you think the average Albertan would choose in a referendum like the one just described?
_____ They would vote Yes to the proposed management program
_____ They would vote No to the proposed management program

When answering this next question, please think about the last vote you completed.

37. Please indicate whether you agree or disagree with the following reasons for why you voted the way you did regarding the Proposed Management Action.

	Strongly Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Strongly Disagree
I do not believe the program will					

actually help to make water supplies more reliable.					
I think we should spend whatever it takes to have virtually no water reliability problems.					
I do not believe my individual vote matters in these types of referendum.					
I think this is the best use of my money.					
It is too much money for the benefits.					
The community’s tap water supply is sufficient and reliable enough.					
I believe that it is a wise investment that will help prevent water supply problems that might happen in the future.					
I already do things to address my own water reliability problems (e.g. maintain bottled water supplies, have a water filtration system, have rain barrels, etc.).					
I do not trust my community water supplier to ensure water reliability.					
Money spent on these types of projects rarely improves the lives of others.					

The Future of Water In Your Community: Vote Two

Suppose that you had a choice between the current situation and a proposed program in a referendum on water reliability. The proposed program would use one of two methods to improve reliability:

- **Drinking water treatment system:** Investments would be made to upgrade and modernize your community's traditional drinking water treatment system to reduce the annual percentage of water outages occurring in the future. Please click here for examples of specific actions.

  Specific drinking water treatment system actions would include:
  - Investing in more modern drinking water treatment systems and increasing the capacity of existing treatment systems,
  - Upgrading and replacing water pipes connecting the water treatment system to households in the community, and
  - Creating more interconnections between drinking water systems and installing backup solutions.

- **Watershed and forest management**: Investments would be made in the watershed where your drinking water comes from to reduce the potential for events such as forest fires to cause water reliability problems downstream. Please click here for examples of specific activities.

  Specific watershed activities would include:
  - Placing buffer strips (i.e. permanent vegetation) along streams to reduce the amount of sediments and debris entering the water,
  - Reducing the amount of hazardous fuels in the watershed to moderate the risk of forest fires, and
  - Forest fire preparedness and response plans to help identify key vulnerabilities and to make responses to fires more effective.

38. Please examine the options below and indicate which option you would vote for.

	Current Situation	Proposed Program
Annual Chance of a Short-term Unexpected Water Outage (a few hours but less than a day)	*(Transfer Responses from Question 24a)* _____________ %	Reduced by half to _____________% (divide Q24 a by 2 and put value in here) [OR – if they get the reduce almost entirely…] Reduced almost entirely to a less than 1% chance
Annual Chance of a Longer-term Unexpected Water Outage (at least 1-2 days)	*(Transfer Responses from Question 24b)* _____________%	Reduced by half to _____________% (divide Q24 a by 2 and put value in here) [OR – if they get the reduce almost entirely…] Reduced almost entirely to a less than 1% chance
Annual Chance of a Boil Water Advisory	*(Transfer Responses from Question 24c)* _____________%	Reduced to by half to _____________% (divide Q24 a by 2 and put value in here) [OR – if they get the reduce almost entirely...] Reduced almost entirely to a less than 1% chance
Method used to improve reliability	Current System	[*Randomize between and include hoverlinks to descriptions]:* Drinking water treatment system improvement Watershed and forest management
Cost of the Program (starting in January 2015)	$0	$___ per year ($__ per month) increase in your

		water bill for 10 years
Indicate which of the programs above you would vote for if you have to select one of these options.	☐	☐

37A. Please rank the following items. Put a 1 for the item that mattered most to you when you were answering the question, a 2 for the next most important item and a 3 for the item that mattered the least to you.

Rank (1 is mattered most, 3 is mattered least)	
	Annual Chance of a Short-term Unexpected Water Outage (a few hours but less than a day)
	Annual Chance of a Longer-term Unexpected Water Outage (at least 1-2 days)
	Annual Chance of a Boil Water Advisory

39. On a scale from 1 to 5, where 1 is uncertain and 5 is certain, how certain are you that this is the option you would choose if this was an actual vote. Please select one response only.

Uncertain		Somewhat Certain		Certain
1	2	3	4	5

40. To what extent do you believe that the voting results collected from you and other survey respondents will be taken into consideration by policy makers?

Not taken into account				Definitely taken into account
1	2	3	4	5

41. What do you think a person like you in your community (i.e. similar demographics, life situation) would choose in a referendum like the one just described?
_____ They would vote Yes to the proposed management program
_____ They would vote No to the proposed management program

42. What do you think the average Albertan would choose in a referendum like the one just described?
_____ They would vote Yes to the proposed management program
_____ They would vote No to the proposed management program

Managing Alberta's Future Water Supply

We are now going to ask you to consider province-wide water reliability management programs relating to boil water advisories.

Boil water advisories are issued by Alberta Health Services as preventative measures to protect public health from waterborne infectious agents that may be present in drinking water. If water is consumed without boiling when there is an advisory, serious health problems can arise ranging from moderate illness to, in very rare circumstances, death. For more information on boil water advisories click here.

The three main causes of boil water advisories are

1. High levels of turbidity in the water,
2. Presence of harmful microbes such as E. coli bacteria, and
3. Equipment and process failures or issues.

When a boil water advisory is issued, the public should boil their tap water for drinking, preparing food, beverages, ice cubes, washing fruits and vegetables and brushing teeth. The water should be brought to a rolling boil for 1 minute to kill all disease-causing organisms.

The typical boil water advisory in Alberta last for 9 days.

Communities have varying chances of being placed under a boil water advisory depending on their source of drinking water and the condition of their water treatment system. The vast majority of boil water advisories are issued for smaller towns and First Nations communities. Approximately 60% of the communities facing boil water advisories in the past have been First Nations communities. The federal government is involved in funding their fair share of water management programs for the First Nations communities under their jurisdiction.

Although the exact numbers change from year to year, over the past 5 years, the average annual number of boil water advisories for different community sizes is presented in the following table:

Community size	Annual number of boil water advisories over past 5 years
Small Communities with less than 500 residents	50
Medium-sized Communities with between 500 and 50,000 residents	4
Large Communities with more than 50,000 residents	1

With new investments in management of the water treatment facilities and the watershed, the number of boil water advisories in Alberta could be reduced. Note that given the state of water treatment facilities and the variation in nature (floods, storms, etc.) it may not be possible to completely eliminate boil water advisories.

The Future of Drinking Water In Alberta: Vote Three

Suppose that you had a choice between the current situation and a proposed program in a referendum on water management. The proposed program would be paid through additional income taxes collected on Albertans. The proposed program would use one of two methods to improve reliability:

- **Drinking water treatment system:** Investments would be made to upgrade and modernize traditional drinking water treatment systems across the province to reduce the likelihood of boil water advisories occurring in the future. Please click here for examples of specific actions.

  Specific drinking water treatment system actions would include:
  - Investing in more modern drinking water treatment systems and increasing the capacity of existing treatment systems,
  - Upgrading and replacing water pipes connecting the water treatment system to households in the community, and
  - Creating more interconnections between drinking water systems and installing backup solutions.

- **Watershed and forest management**: Investments would be made in watersheds to reduce the potential for events such as forest fires to cause water reliability problems downstream. Please click here for examples of specific activities.

  Specific watershed activities would include:
  - Placing buffer strips (i.e. permanent vegetation) along streams to reduce the amount of sediments and debris entering the water,
  - Reducing the amount of hazardous fuels in the watershed to moderate the risk of forest fires, and
  - Forest fire preparedness and response plans to help identify key vulnerabilities and to make responses to fires more effective.

43. Please examine the options below and indicate which option you would vote for.

	Current Situation in Alberta	Proposed Program
Annual Number of Boil Water Advisories in **Small Communities with less than 500 residents**	50	(5,15,25,50)
Annual Number of Boil Water Advisories in **Medium-sized Communities with between 500 and 50,000 residents**	4	(1,2,3,4)
Annual Number of Boil Water Advisories in **Large Communities with more than 50,000 residents**	1	(0,1)
Method used to improve reliability	Current System	Randomize between and include hoverlinks to descriptions: Drinking water treatment system Watershed and forest management
Cost of the Program (starting in 2015)	$0	$___ **per year** (__$ per month) increase in your **provincial income tax** for 10 years
Indicate which of the programs above you would vote for if you have to select one of these options.	□	□

44. On a scale from 1 to 5, where 1 is uncertain and 5 is certain, how certain are you that this is the option you would choose if this was an actual vote. Please select one response only.

Uncertain		Somewhat Certain		Certain
1	2	3	4	5

45. To what extent do you believe that the voting results collected from you and other survey respondents will be taken into consideration by provincial policy makers?

Not taken into account				Definitely taken into account
1	2	3	4	5

46. What do you think a person like you in your community (i.e. similar demographics, life situation) would choose in a referendum like the one just described?
_____ They would vote Yes to the proposed management program
_____ They would vote No to the proposed management program

47. What do you think the average Albertan would choose in a referendum like the one just described?
_____ They would vote Yes to the proposed management program
_____ They would vote No to the proposed management program

48. When you think about whether the interests of the population will be taken into account when managing water quality and quantity, to what extent would you trust government resource management institutions?

_____ Completely trust
_____ Somewhat trust
_____ Somewhat not trust
_____ Completely not trust

Follow-up Questions
Now we just have a few more questions to ask you that will help us understand your responses compared to other members of the public.

D1. Did you grow up in a small town or rural area?

___Yes
___No

D2. Do you rent or own the place you currently reside?

___Rent
___Own

D3. Are you a member of a watershed protection community group?

___Yes
___No

D4. Do you consider that the amount of income tax you pay is...? Please select one response only.

___Too high
___About right
___Too low
___Don't know

D5. Do you consider that the amount you pay for your water bill is...? Please select one response only.

___Too high
___About right
___Too low
___Don't know

D6. If a provincial election were held today, how would you vote provincially? Please select one response only.

___Alberta Party
___Alberta Liberal Party
___Alberta New Democratic Party
___Progressive Conservative Party of Alberta
___Wildrose Party
___I am not eligible to vote
___I would choose not to vote
___Other (Please type in your response)
___Don't know
___ Prefer not to say

D7.Compared to others your age, would you say your health is? Please select one response only.

___Much better
___Somewhat better
___About the same
___Somewhat worse
___Much worse
___Don't know

D8. In the past 12 months, have you ever been a patient overnight in a hospital, nursing home, or convalescent home?

___Yes
___No
___Decline to respond

D9. Which, if any, of the following long-term health conditions do you or members of your family have? Please select all that apply. Please select at least one response (which could be none of the above) in each column.

Health Conditions	Myself	Household Member
Food allergies		
Any other allergies		
Asthma		
Arthritis or rheumatism		
Back problems, excluding arthritis		
High blood pressure		
Migraine headaches		
Chronic bronchitis or emphysema		
Sinusitis		
Diabetes		
Epilepsy		
Heart disease		
Cancer (Please specify type)		
Stomach or intestinal ulcers		
Effects of a stroke		
Any other long-term condition that has been diagnosed by a health professional (Please specify)		
None of the above		

D10. How many individuals live in your household?

____

D11. Are you…?

___Male
___Female

D12. What is your birth date?

____

D13 What is your postal code?

____
___Decline to respond
___Don't know

D13b Could you please provide the first 3 digits of your postal code? We need this information to make sure that survey responses represent the entire province of Alberta.

____
___Decline to respond
___Don't know

E1. Please enter any additional comments you may have about this survey in the space provided.

Thank you for your time. Good bye.

Appendix B: NLOGIT commands for Spike models

```
?Import data
RESET
IMPORT;FILE="C:\Users\aappiah\Dropbox\Thesis\Data\long data.xls"$

?Set panel
setpanel;group=id;pds=pa$

? Create indicators for participation and willingness to pay offered bid amounts
create; if (part=0) z1=1$
create; if (vote=0) z2=1$
create; if (vote=1) z3=1$

?Estimate spike model assuming a logistic CDF for WTP

skip;
minimize;labels=a,c,d,e,f;
start= 1.17, 0.0107,0.1,0.1,0.5;
fcn=-
(z1*log(1/(1+exp(a+d*relative+e*type+f*order)))+z2*log((1/(1+exp(a+d*relative+
e*type+f*order-c*cost)))
-(1/(1+exp(a+d*relative+e*type+f*order))))+ z3*log(1/(1+exp(-a-d*relative-
e*type-f*order+c*cost))));wts=weight;panel$

?Estimate spike model assuming a lognormal CDF for WTP
skip;
minimize;labels=a,c,d,e,f;
start= 1.17, 0.0107,0.01,0.5,0.01;
fcn=-(z1*log(1-phi(a+d*relative+e*type+f*order))+z2*log((1-
phi(a+d*relative+e*type+f*order-c*log(cost)))-(1-
phi(a+d*relative+e*type+f*order)))+
z3*log(phi(a+d*relative+e*type+f*order-c*log(cost))));panel;wts=weight$

?Estimate spike model assuming a normal CDF for WTP

skip;
minimize;labels=a,c,d,e,f;
start= 1.17, 0.0107,0.01,0.5,0.01;
fcn=-(z1*log(1-phi(a+d*relative+e*type+f*order))+z2*log((1-
phi(a+d*relative+e*type+f*order-c*cost))-(1-phi(a+d*relative+e*type+f*order)))+
z3*log(phi(a+d*relative+e*type+f*order-c*cost)));panel;wts=weight$
```