# The use of discrete choice experiments and a coupled socio-hydrological model to inform water policymaking in the Okanagan region of British Columbia

by

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## Ethics Statement

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

a. human research ethics approval from the Simon Fraser University Office of Research Ethics

or

b. advance approval of the animal care protocol from the University Animal Care Committee of Simon Fraser University

or has conducted the research

c. as a co-investigator, collaborator, or research assistant in a research project approved in advance.

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## Abstract

The Okanagan region in southeast British Columbia is a unique place offering opportunities for agriculture, tourism and other commercial enterprises, along with attractive residential amenities such as stunning panoramas and lakeside communities. The Okanagan also features high per capita water use and is confronting rapid population growth, altered landscapes, and climate change induced alterations to the water supply cycle. Decision makers managing freshwater systems in the Okanagan need to balance the competing tasks of meeting growing demands for water and protecting hydrological processes supporting the broader ecosystem. To do so, they need representative information about the complex interactions between physical and social processes in the Okanagan Basin watershed. In this thesis, I examine how discrete choice experiments and a coupled socio-hydrological model can be used to advance understanding of the preferences and behaviour of water users in the Okanagan, and to inform water policymaking. First, I use a discrete choice experiment to investigate and model the preferences of residents for landscaping options affecting outdoor water use. I find that residential preferences for lawns in the Okanagan differ from the current characteristics of many lawns in the region, offering the potential for policies to promote changes to reduce water use. I then use similar methods to examine and model the preferences of farmers concerning drought response policies in an adjacent agricultural setting. I find that these farmers have preferences for drought response plans that contain opportunities to trade water during droughts and that a moderate reduction of water supply during droughts may also be acceptable to them. Finally, I develop and demonstrate the application of a coupled socio-hydrological model that links the behavioural model developed from my resident study with a hydrological model of the Okanagan Basin. I find that discrete choice models can be used to prepare a valuable proxy for human behaviour to inform water related decisions and that the coupled socio-hydrological model presents a more sophisticated representation of human-water system interactions than conventional hydrological models, improving the information available to support decision makers.

**Keywords**: decision support tools; water policymaking; water demand management; discrete choice experiment; coupled socio-hydrological modelling

## Dedication

*I dedicate my thesis to my daughter Meadow. I started this thesis when Meadow was a young infant and I have watched her grow to become a beautiful person. I am blessed to have her in my life. I also dedicate this thesis to Dr. Wolfgang Haider, to whom I owe a new passion for choice modelling and for exposing me, a life-long engineer, to the value of social sciences. For that I am eternally thankful.*

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# Chapter 1.

# Introduction

This thesis consists of three manuscripts for journal articles presented as individual chapters, along with this introductory chapter and a concluding chapter that links the three studies and draws lessons from the research as a whole. Each of the journal manuscripts has its own introduction, methods, conclusion, and list of references. The research was all undertaken as part of a single project designed to examine the potential of discrete choice experiments and a coupled socio-hydrological model to inform water policy making in the Okanagan Basin region of British Columbia, Canada. In this introduction, I provide an overview of the research objectives and rationale, and discuss the context of the project.

## 1.1. Decision support tools, socio-hydrology and water system management

Managing a water supply system is a complex problem, involving interactions between surface water and ground water resources with many physical, social, and biophysical processes operating across diverse geophysical and climatic conditions. For water systems in rural-residential settings, this complexity includes the challenges of balancing the demands of agricultural and urban water uses, ensuring adequate supply for all uses, and maintaining stocks and flows for environmental needs. To deal with this complexity, water managers often rely on decision support tools, including hydrological models representing aspects of watershed catchment areas such as river flows (Nash and Sutcliffe 1970) and rainfall runoff (Beven 2011), or models of water management and allocation (e.g. the Water Evaluation and Planning system – WEAP (Yates et al. 2005)), or models of the predicted impacts of climate changes (Merritt et al. 2006).

Broadly speaking, decision support tools are designed to facilitate better decisions by providing information about the problem being addressed, the context (past, present and future), the trade-offs involved with various potential actions, and the possible outcomes. Decision support tools are used in a wide variety of decision making applications and contexts, and may take the form of decision aides (e.g., decision matrices, rankings, option screenings), complex numerical models (Pyke et al. 2007), or even strategies for organizational design and work processes (Bruen 2008). Most contemporary forms of decision support, however, use some type of computer-based system to aid in decision making and problem solving (Shim et al. 2002).

Formalizing decision-support and developing support tools requires an understanding of the decision-making context and the decision making process. For instance, decision-making for water supply systems involves evaluating trade-offs among needs in order to manage water demand and deliver adequate supplies of water, given available water sources and storage. Salewicz and Nakayama (2004) conceive of this process as a three-part structure made up of the following elements:

- the system or physical boundary under consideration — the system(s) in question may take the form of an individual watershed, an urban water system, or even a single water treatment plant or dam;
- the problem which requires a decision — e.g., the problem of allocating limited water supplies to meet the needs of agricultural, industrial and residential customers while minimizing the consumption of water; and
- the decision-maker — the agent responsible for taking action to resolve conflict, achieve political objectives, or balance trade-offs between different water uses.

Historically, decision support tools for water management have largely focused on the natural sciences, drawing on physical constructs to represent and conceptualize water system processes using hydrological modelling sciences (Blöschl and Sivapalan 1995; Andreu et al. 1996; Westphal et al. 2003; Williams et al. 2004). Often, such hydrological models have been prepared to represent the “natural” state of a water system, and then used to answer questions such as “what supply mixes will improve water quality?”, and “how much water storage will be needed to meet anticipated future demand?” Proponents of this approach to decision support for water management argue that a detailed technical representation of the water system provides the most complete and informative picture of how ecological systems might respond to natural dynamics and human actions (Freeze and Harlan 1969; Abbott and Refsgaard 1996). In water systems that supply water for human use, however, such modelling approaches have been criticized for ignoring or oversimplifying socio-hydrological interactions (Carey et al. 2014; Sivapalan and Blöschl 2015; Blair and Buytaert 2016; Krahe et al. 2016). In such water systems, human systems interact with and modify hydrological cycles, while hydrological systems influence the development and formation of human systems.

One approach to understanding and managing interconnected social and hydrological systems is to supplement physical models with information about human behaviour, such as forecasts of demographic change and economic activity. For instance, water demand forecasts are often derived from historical water use data for various sectors (e.g. utility billing data) (Coombes et al. 2000; Mitchell et al. 2001; Liu et al. 2014; Avni et al. 2015). This empirical evidence can then be applied in end-use models (Whiteside et al. 2008; Blokker et al. 2010) or in management models to assess the trade-offs of various water supply options (Yates et al. 2005). Such approaches, however, may lack the capacity to predict behaviour in response to policy options and/or conditions outside of what has been experienced historically. Hydraulic models that rely on historical water use observations to describe human behaviour may therefore only provide limited assistance to water resource management decision-making.

Another way of taking into account human factors in water management is to use a decision support tool to elicit a range of viewpoints from water users and other stakeholders on a decision-making problem. For instance, decision support tools can be used to explore various scenarios with stakeholders, in the hope of finding acceptable compromises (Bruen 2008). In these instances, stakeholders provide the framework for acceptable outcomes that are informed by decision-support and interpreted by the decision-maker (Bhave et al. 2014; Safavi et al. 2015).

In recent years, recognition of the linkages and feedbacks between human systems and ecological systems has led to the development of more complete coupled models of socio-ecological systems in many areas of resource management (Bonnicksen 1991; Mangel et al. 1996; Berkes et al. 1998; Gunderson and Holling 2002). Such coupled models represent dynamic feedbacks among actors, institutions, and resources at multiple scales, and have been applied in fisheries, forestry, wildlife management and other fields (Schlueter et al. 2012). For water supply systems, the recognition of human-water interconnections has fostered research on hydro-ecological modelling (Akter et al. 2014), natural and human system dynamics (Fernald et al. 2012), hydro-economic modelling (Kragt et al. 2011; Hurd and Coonrod 2012), socio-economic tools applied to water systems (Koundouri et al. 2015), agent based models (Barthelemy et al. 2002; Lansing et al. 2009), integrated water resource management (Pahl-Wostl et al. 2007; Barthel et al. 2008), hydro-social modelling (Carey et al. 2014), socio-hydrosystems (Lanini et al. 2004; Liu et al. 2008), and the recently conceived fields of socio-hydrology (Sivapalan et al. 2012) and socio-hydrological modelling (Viglione et al. 2014).

The research presented in this thesis contributes to these new fields in which social modelling is coupled with hydrological modelling. Although I conducted most of my data-gathering and modelling work before Sivapalan et al. (2012) published their conception of socio-hydrology, or Viglione et al. (2014) defined what they call socio-hydrological modelling, my research aligns well with their work. Sivapalan et al. (2012) present socio-hydrology as the study of two-way feedbacks that lead to the coevolution of human and water systems. They suggest that previous attempts to represent human-water systems have focused on controlling these systems, whereas socio-hydrology focuses on observing, understanding and predicting future trajectories of co-evolution of coupled human-water systems. Thus in preparing decision support tools and models, the coupling of human-water systems may be considered a requirement for future investigations and such models should represent the nature of both systems (Sivapalan et al. 2012; Troy et al. 2015).

Examples of socio-hydrological modelling include Di Baldassarre et al.'s (2013) conceptualization of a model of the interactions between human settlements and flooding, which was further developed in Viglione et al. (2014). Srinivasan (2015) prepared a model to simulate the interactions between human, engineered and hydrological systems in Chennai, India. Elshafei et al. (2014) developed conceptual models representing feedbacks between society and hydrology in river basins affected by irrigation.

Hydrologists and modellers are beginning to recognize the importance of including human variables in models of watersheds, yet there remains an active debate over the constructs of socio-hydrological models. Central to this debate are the ongoing discussions of the trade-offs modellers face between generality, precision, and realism as originally presented by Levins (1966) and applied to socio-hydrology by Troy et al. (2015), and the methodologies being applied to improve the modeled linkages between human and water systems (Di Baldassarre et al. 2015). My research lies within this debate as the coupled socio-hydrological model I present in Chapter 4 focuses on improving the realism of the representation of human behaviour in hydrological modelling by using a discrete choice experiment to model human behaviour and then linking this information to a model of the hydraulic system. Thus, the coupled model I prepared illustrates a new method for linking human and water systems.

## 1.2. Modelling social and hydrological systems in the Okanagan Basin

My research explores how hydraulic modelling sciences and social sciences research can be linked to advance understanding of the connections between human and water systems in the Okanagan Basin. First, I use a discrete choice experiment to investigate and model the water-related preferences of residential water users in an urban setting in the Okanagan (Chapter 2). Then, I use similar methods to examine and model the preferences of farmers in an adjacent agricultural setting (Chapter 3). Finally, I develop and demonstrate the application of a coupled socio-hydrological model that links the behavioural model developed in Chapter 2 with the Water Management and Allocation System (WEAP) hydrological model of the Okanagan Basin (Chapter 4). I examine how the information gathered to prepare a coupled model and the outputs of that model can be used to inform water policymaking.

### 1.2.1. Water management in the Okanagan Basin

Management of water in the Okanagan Basin watershed (Fig. 1.1) is currently being challenged by population growth and urbanization, climate change, and increased water withdrawals for agriculture (Hrasko et al. 2008). The Basin has the highest ratio of human population to annual surface water yields of any basin in Canada (Statistics Canada 2010) and relies on winter snowfall for the majority of its annual water supply, as summers are typically warm and dry (Merritt et al. 2006). The risk of temporary and long-term water stress in the region is increasing under climate change (Merritt et al. 2003; Van der Gulik and Neilsen 2008; Cohen et al. 2011). Over the past century the depth and duration of snowpack has declined, and from 1916 to 2000 winter maximum temperatures increased by 2.0 °C (Cohen and Kulkarni 2001; Taylor and Barton 2004). Agriculture represents the single largest use of water in the Okanagan watershed and water withdrawals for this use are expected to increase as climate change introduces longer growing seasons (Summit Environmental 2010a; Van der Gulik et al. 2010). Agriculture is a key industry for the Okanagan and is one of the region's leading economic engines (Schorb 2006). However, landscapes across the Okanagan are shifting from being dominated by working agricultural lands to feature more residential and recreational development.

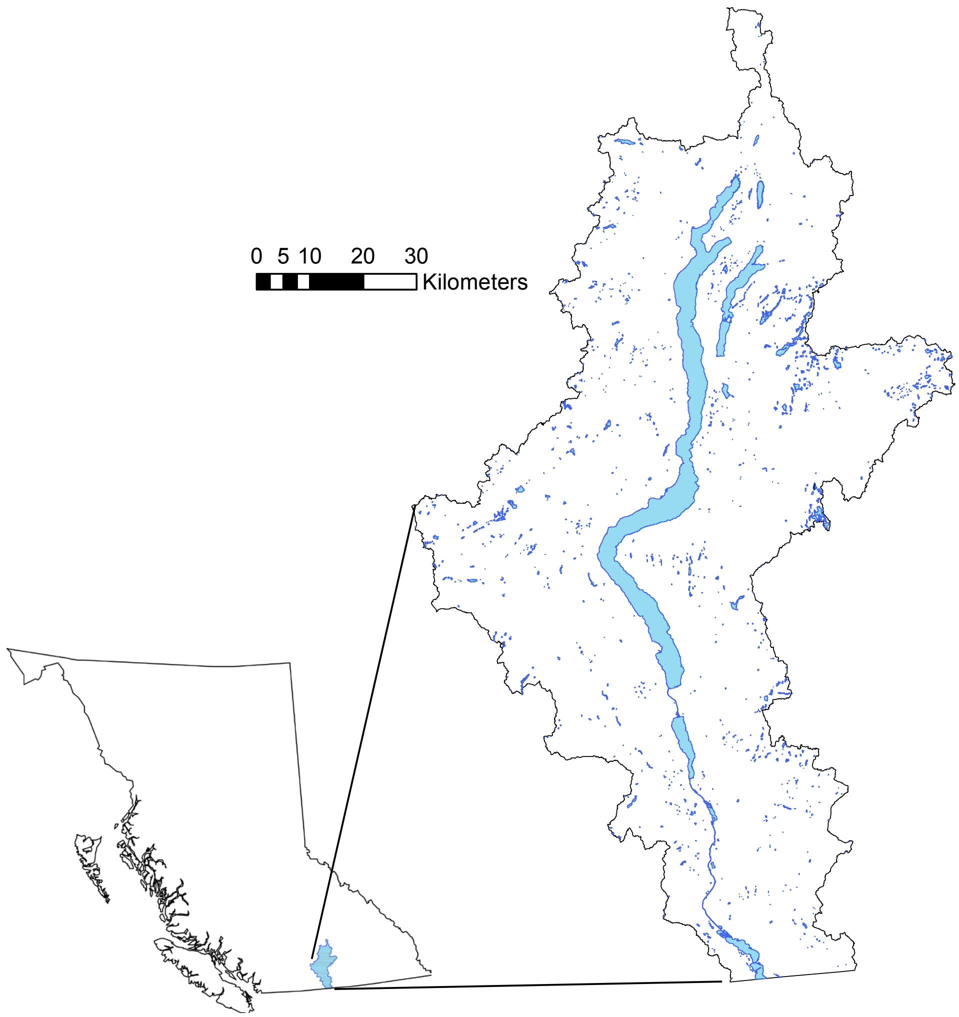


**Fig. 1.1. Map of the Okanagan Basin in British Columbia, Canada**
Source: ArcGIS 10.2

In response to these challenges, in 2004 the Okanagan Basin Water Board initiated the Okanagan Water Supply and Demand Project to develop better data for water and land use planning in the region. Results from Phase 1 of the project identified the need for comprehensive models to evaluate the potential impacts of population growth, climate change, and shifting land use in the Okanagan (Summit Environmental 2005). Phase 2 of the project was completed in 2010 and produced two models for the Okanagan Basin. The first, the Okanagan Water Demand Model, estimated water needs for residential, agricultural, and industrial and commercial uses, based on land survey data, GIS and cadastral mapping of crop types – including turfgrass, irrigation system types, soil properties, and climatic data (Summit Environmental 2010b). The second model, the Okanagan Water Accounting Model, estimated natural stream-flows and the effects of water storage and extractions on stream-flows and lake levels in the Okanagan Basin (DHI Water and Environment 2010).

The models prepared in Phase 2 of the Okanagan Water Supply and Demand Project were developed using hydrological principles to present to decision makers a macro-level overview of the water system and the demands water users exert on water supply sources. Neither of these models included a coupled social component. These models did, however, provide the hydrologic basis for my research.

Phase 3 of the Okanagan Water Supply and Demand Project began in 2010. The objectives of Phase 3 included increasing the availability of data, refining modelling tools, consulting the public, and developing and evaluating policies for improving the hydrologic sustainability of the region. The initiation of Phase 3 presented an opportunity for me to improve the information and models available about the preferences of residential and agricultural water users in the Okanagan, and also explore the possibility of using this research to improve the predictive capacity of the existing models used by the Okanagan Basin Water Board.

### 1.2.2. Collaborative development of the research and models

I used a modified Adaptive Environmental Assessment and Management (AEAM) workshop methodology to consult with and involve stakeholders in the development of my research design and models. I adapted the AEAM workshop structure outlined in Jones and Greig (1985), including four stages: an initial scoping workshop, a second workshop that focused on further bounding the scope of the investigation, several subsequent workshops about the design of the choice experiments to be included in my surveys and about the results of my surveys and modelling, and a final workshop that focused on defining scenarios for the coupled socio-hydrological model and applying the choice experiment results to inform policymaking. Participants in this process included individuals from Okanagan water providers and irrigation districts, the BC provincial and local governments, Agri-food Canada, agriculture associations, and the local academic community. The AEAM workshops provided context and guidance for my research while also fostering learning among participating stakeholders and support for the research outcomes.

### 1.2.3. Focusing on human behaviour important to the Okanagan

My initial workshop session in the Okanagan, and my early discussions with water managers there, highlighted a key issue for water management in the region: an increasing proportion of regional water supplies was being allocated to meet residential water demand, but there was still a management priority to ensure adequate water supplies to sustain the region's agricultural base. I decided to examine both sides of this issue, by conducting research on the preferences of residential water users and those of agricultural water users. For the reasons discussed below, I focused on the preferences of residential water users about their lawns and their outdoor water use under various possible policies, and the preferences of agricultural users about water use and potential strategies for drought response planning.

Studies examining the trend of residential water use in the Okanagan at the time I began my research showed a decline in indoor water use but an increase in outdoor water use (Alexander and Robson 2007; DHI Water and Environment 2010). One major factor in this increase in outdoor water use appeared to be the ongoing construction of single family homes featuring lawns, and the accompanying water use needed to maintain these lawns (Hrasko et al. 2008; City of Kelowna 2009; Maurer 2010). I began my research in this area by examining behaviour concerning residential irrigation of lawns. I conducted a focus group based survey of residents' attitudes toward water efficient technology options for irrigation. While reviewing responses with residents I noted that they frequently discussed the attributes of their lawns and how these attributes influenced their decisions about investing in irrigation technologies. For instance, residents with smaller lawns commented that they had already made an investment in reducing water use by having a smaller lawn, while residents who chose to water less in the summer months shared stories of how their lawns appeared browner than those of their neighbours. These discussions about residents' preferences concerning lawn appearance and water use, and the influence that attributes of a resident's existing lawn seemed to have on their decision making, led me to develop a subsequent survey and model of residential outdoor water use (see Chapter 2). In that study, I examine the preferences of owners of detached homes for three approaches to reducing the irrigation requirements for their residential lawns: reductions in lawn sizes; subsidies for removing or replacing lawns; and the use of drought-tolerant turfgrass. Each respondent's current lawn (i.e., the status quo) was included as a possible choice in the survey, and the attributes of the current lawn were used in constructing the set of alternatives. The research presented in Chapter 2 provides important information about homeowners' preferences for lawn attributes, and how existing lawn features affect those preferences. The results will be useful to decision-makers considering options for reducing outdoor irrigation requirements in the Okanagan.

While preparing the residential study, I had been meeting with agricultural groups and farmers throughout the Okanagan with the intention of investigating farmers' preferences about the adoption of water efficient irrigation technologies. Several items hindered this direction of research. First, the Okanagan agricultural landscape is diverse with farmers growing several types of crops on each property; each crop using different types of irrigation equipment and practices (Van der Gulik and Neilsen 2008). Addressing this diversity would require preparing multiple experiments to address each crop type. Second, many farmers expressed the opinion that they were already doing as much as they could to use water efficiently and that they would likely make an investment in new technology only if they were changing crops for other reasons. This observation suggests that a complex mix of factors related to crop selection is included in the decision about whether to adopt water efficient technology, rather than being just a decision focused on reducing water use and water cost (Conrad 2013). Third, the adoption rates of water efficient irrigation technologies in the Okanagan appeared to be declining following previous subsidy programs (Suess et al. 2012). Fourth, the range of potential irrigation technologies varied greatly, making it difficult to design a survey that would be suitable for all farmers across the Okanagan. Given these issues, I decided to examine another aspect of agricultural water demand that is likely to become increasingly important with residential growth and climate change – managing agricultural water demand during periods of drought (see Chapter 3). I used a discrete choice experiment to investigate the preferences of farmers about three options for drought response policies in the Okanagan: mandatory water reductions, mandatory re-allocations of available water, and opportunities for water trading.

Farmers' preferences concerning drought response plans are important for managing water demand in the Okanagan for several reasons. First, as previously mentioned, agricultural water use represents the greatest consumptive use of water in the Okanagan Basin. Therefore, the cooperation of farmers during water shortages is vitally important. Second, water licensing in British Columbia is based on prior appropriation principles, under which the water rights of senior license holders have priority over junior license holders, even in times of shortage (Percy 1988). Farmers in the Okanagan often hold senior licenses. Third, a proposal in 2010 by the BC provincial government to modernize the *Water Act* stimulated debate in the province about various water allocation mechanisms, including water trading, water restrictions, and protection for environmental flows (British Columbia Ministry of Environment 2010). However, there was little data available on the preferences of farmers concerning allocation options during water shortages. The research presented in Chapter 3 helps to fill this important gap for policymakers who are considering options for drought response planning in the Okanagan.

### 1.2.4. Developing a representation of water user's behaviour

I elected to use survey-based discrete choice experiments to investigate the preferences and likely behaviour of residential and agricultural water users in the Okanagan. Discrete choice experiments, which are based on random utility theory (McFadden 1974), have been widely used to evaluate the preferences and attitudes of consumers in relation to future or hypothetical scenarios. In a typical discrete choice experiment, individuals consider trade-offs between competing alternatives described by several attributes.

A discrete choice experiment is a "stated preference" method, in that preference data are derived from survey responses in which respondents state what their choice would be in a hypothetical scenario. In contrast, "revealed preference" data come from observations of actual behaviour. Discrete choice experiments present a viable alternative to revealed preference methods when revealed data are not readily available, or when revealed data may be insufficient to represent new situations that are outside the range of past behaviour observations, such as considering the impact of conditions that have not previously existed, or alternatives that have not previously been offered.

The statistical analysis of stated preference data from choice experiments often uses the multinomial logit (MNL) model (e.g., (McFadden 1974; Adamowicz et al. 1998)). MNL models describe the probability of choosing one alternative over another (Louviere et al. 2000), which, when applied to water use, indicates the probability that a water user will behave in a particular way given a number of independent variables, or attributes, that were present in each one of the evaluated scenarios. The MNL model has the potential to provide insight into water use behaviour and to generate predictive parameters that could be coupled to a hydrological model. Choice modelling techniques allow for modelling stakeholders' demand response to future options or management policies, thus providing crucial information for coupled models and decision-making.

An example of such a linked approach is demonstrated in Kelly et al. (2007) where a discrete choice experiment was used to estimate stated behaviour of tourists for various transportation planning scenarios. The resultant MNL model was then integrated with a technical energy-use model to create behaviourally shaped estimates of energy consumption and green house gas emissions. The resulting human-energy model can be used to evaluate additional future planning scenarios and develop transportation policies.

When I began my research, only a few studies had applied discrete choice experiments to issues of water management. Haider and Rasid (2002) used a multivariate stated preference model as a formal method of assessing the trade-off behaviour of municipal residents of Thunder Bay, Ontario, based on their preferences for the source of municipal water supply. In that study, residents were asked to choose repeatedly from a set of alternatives, which displayed different configurations of water rates (increases of 2.5% to 5% over 10 years), water pressures (reduced, same, increased), and water taste (worse, same, improved) for three alternative sources of water supply - Bare Point, Loch Lomond (affected by a 1997 Boil Water Advisory), or combined. The results indicated that, despite the suggestion of a lower water rate with the Bare Point option, residents' preferences for Loch Lomond were significant, irrespective of the water rates. Other choice studies of water management in existence at the time I began my research included:

- Blamey et al. (1999) and Gordon et al. (2000), examined community preferences for alternative water supply options in the Australian Capital Territory;

- Willis et al. (2005), examined benefits of water service to water company customers across 14 factors;

- Hensher et al. (2005) examined consumer willingness to pay for water service benefits; and

- Hurd (2006) examined landscape choices in response to changes in water price and moral suasion.

During the time that I conducted my research and wrote this thesis, more discrete choice experiments examining water use and management appeared in the literature, including:

- examining implicit prices associated with urban water supply attributes (Hatton MacDonald et al. 2010);

- identifying stated preferences for aquifer management plans in water scarce regions (Birol et al. 2010);

- assessing public willingness to pay for improvements to drinking water quality (Latinopoulos 2014; Brouwer et al. 2015);

- willingness to pay to avoid watering restrictions (Cooper et al. 2011);

- willingness to accept payments for setting aside agricultural land to provide for water quality setbacks (Broch et al. 2012; Beharry-Borg et al. 2012; Lienhoop and Brouwer 2015);

- preferences for policy design of water supply options (Katayama et al. 2009); and

- willingness to pay for water under different water allocation programs (Speelman et al. 2010; Chellattan Veettil et al. 2011a; Chellattan Veettil et al. 2011b; Alcon et al. 2014).

The research presented in this thesis contributes to this expanding use of choice experiments for water management issues, offering novel applications of choice experiments to study policies for agricultural drought response plans, and the influence of existing lawn attributes on consumer lawn choices using a MNL choice model, as well as the first known instance of coupling a hydrologic model with a MNL model of preferences.

### 1.2.5. Developing a coupled socio-hydrological model

As a decision support tool, the previously mentioned Water Management and Allocation System (WEAP) model, developed by Raskin et al. (1992) and the Stockholm Environment Institute, has been widely used to explore human-water interactions in a number of case studies:

- Swiech et al. (2012), analyzed the impacts of a reservoir for improved agricultural production in the Yarabamba region, Peru;

- Höllermann et al. (2010) applied different scenarios of socio-economic development and climate change to review Benin's future water situation through 2025;

- Bhave et al. (2014) used WEAP to model the effect of stakeholder prioritized climate change adaptation options for the Kangsabati river catchment in India;

- Hellegers et al. (2013) used WEAP to model trade-offs between water supply and demand to examine deficits against climate change scenarios in Iran, Morocco and Saudi Arabia; and

- Safavi et al. (2015) used expert knowledge to prepare underlying data in a river basin model using WEAP for the Zayandehrud River Basin.

WEAP has also been previously used to examine water supply and demand in the Okanagan basin. Harma et al. (2012) first utilized WEAP to investigate future climate scenarios in unregulated and reservoir-supported streams that supply the District of Peachland, in the Okanagan.

After the initiation of my research, WEAP was selected by the Okanagan Basin Water Board as a platform for investigating the effects of the prior appropriation principle used in the British Columbia water licensing system (Summit Environmental 2013). The resulting Okanagan Hydrologic Connectivity Model examines connected water use between communities and provided the Okanagan Basin Water Board a decision support tool to inform regional drought response plans and new water licensing decisions.

I selected WEAP to explore the coupling of a MNL model with a hydrological representation of the Okanagan basin to inform policymaking. I selected WEAP because of its flexibility in structuring water demand data by various measures of social and economic activities and because the Okanagan Basin Water Board had adopted WEAP as a water management tool. A more detailed explanation of WEAP is provided in Chapter 4.

I initially intended to explore coupled socio-hydrological modelling by combining the results of my discrete choice experiments with an existing model managed by the Okanagan Basin Water Board. After the development of the WEAP based Okanagan Hydrologic Connectivity Model I selected this model for coupling. However, upon further investigation I identified that the representation of water demand in the Okanagan Hydrologic Connectivity Model did not provide an adequate mechanism for coupling a MNL model. The Okanagan Hydrologic Connectivity Model utilized water demand data provided by the Okanagan Water Demand Model (Summit Environmental 2010b). During simulation the Okanagan Hydrologic Connectivity Model would read files generated by the Okanagan Water Demand Model. This separation of water demand data would require me to either modify how water demand was represented in the Okanagan Hydrologic Connectivity Model (i.e. eliminating the file level reads and parameterizing water demand in the model) or modifying the Okanagan Water Demand Model (i.e. embedding the MNL model in the Okanagan Water Demand Model and regenerating the output files (Fig. 1.2) – a less than ideal option as this would require regenerating output files each time a new scenario was to be evaluated).

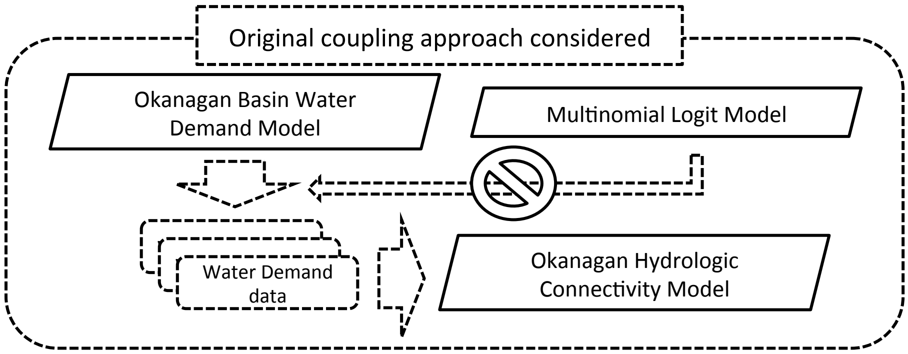


**Fig. 1.2. Original coupled socio-hydrological model approach**

Rather than modify the representation of water demand within either the Okanagan Water Demand Model or the Okanagan Hydrologic Connectivity Model, I elected to prepare a new model based on the structure and data provided by the Okanagan Basin Water Accounting Model, Okanagan Water Demand Model, and Okanagan Hydrologic Connectivity Model (Fig. 1.3). The Okanagan Hydrologic Connectivity Model provided the hydrological structure (e.g. rivers, reservoirs, lakes) for constructing my coupled model in WEAP, the Okanagan Basin Water Accounting Model provided hydraulic data (e.g. natural stream flow data, reservoir inflow and outflow), and the Okanagan Water Demand Model provided water demand data for water use outside my study area. The resulting WEAP model provided a platform for coupling a MNL model of human behaviour and demonstrating the application of a coupled socio-hydrological model to inform water policymaking in the Okanagan Basin (see Chapter 4).

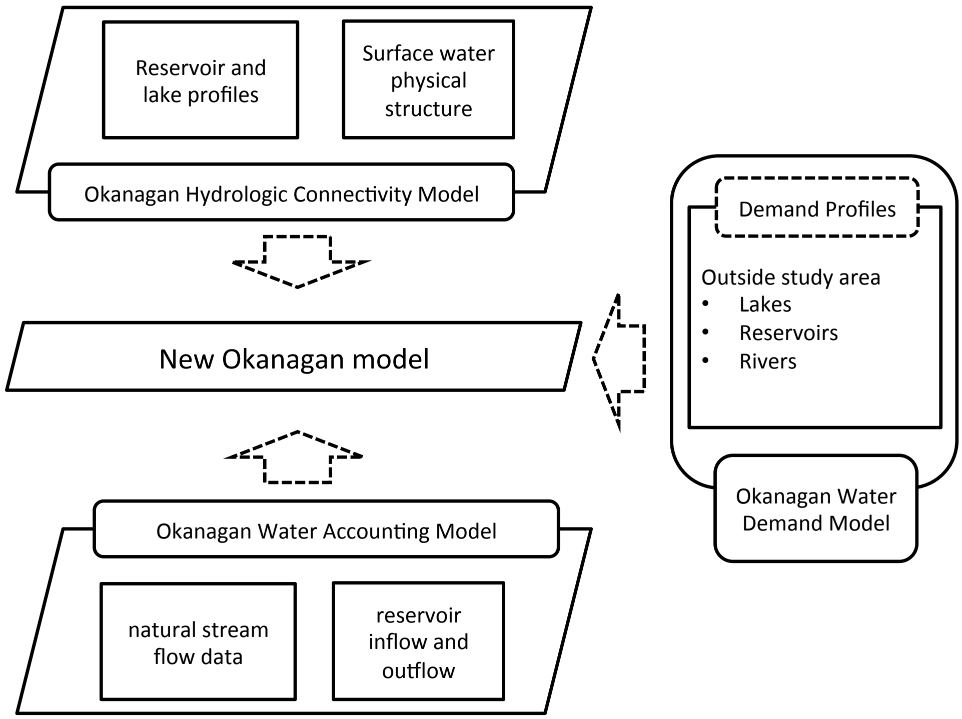


**Fig. 1.3. Development of new Okanagan Model for coupling a MNL model of human behaviour**

## 1.3. Structure of the Thesis

The next three chapters present different components of my research. Chapter 2 and Chapter 3 apply discrete choice experiments to study residential and agricultural water use, and discuss how information garnered from the experiments could inform policymaking in the Okanagan. Chapter 4 presents the coupling of behavioural data derived from the residential experiment in Chapter 2 with a hydrological model prepared in WEAP. In Chapters 2 and 3, potential implications for choice modelling research from a water context are examined, and in Chapter 4 the contribution of stated preference research to the field of socio-hydrological modelling is presented. In Chapter 5, I summarize and draw lessons from my research and suggest directions for future research.

Appendix A lists the publications and presentations in which the contributions of this research have previously been disseminated. I include full copies of three publications related to this research as additional appendices. The first publication is a synopsis of decision support systems I prepared as a chapter in the book “The Water–Energy Nexus in the American West” for Professor Douglas Keeney when initially reviewing literature on decision support systems and researching the interactions between human systems and water and energy systems (Conrad 2012a). A copy of this chapter is included with permission from Edward Elgar Publishing Limited in Appendix B. The second publication provides an expanded discussion of the choice experiment survey methodology and a description of additional results from the survey of residents forming the study I describe in Chapter 2. I prepared this report for the Okanagan Basin Water Board as part of a Natural Resources Canada Regional Adaptation Collaborative Program grant and a copy of this report is included in Appendix D (Conrad 2012b). The third publication provides a discussion of farmer interviews and an expanded description of respondent data from the agricultural study I present in Chapter 3. I prepared this report for the Okanagan Basin Water Board as part of an Agriculture Environment and Wildlife Fund grant and a copy is included in Appendix F (Conrad 2013). Appendices C and E are copies of the resident questionnaire and agricultural questionnaire, respectively.

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# Chapter 2.

# How current lawn attributes affect preferences concerning water conserving lawn options: An individualized choice experiment in Kelowna, British Columbia

*This chapter has been submitted to the Journal of Water Resource Planning and Management as Conrad, S., Pipher, J., and Haider, W., "How current lawn attributes affect the preferences of water conserving lawn options: An individualized choice experiment in Kelowna, British Columbia". I designed and led the fieldwork for this research. I additionally authored the majority of the text and conducted the majority of the data analyses.*

# Abstract

This paper contributes to the study of water conservation and policies governing land use in residential landscapes. We employed a choice experiment to examine the stated preferences of residents of detached homes in the City of Kelowna, British Columbia, for three approaches to reducing the irrigation requirements for their residential lawns: restrictions on lawn sizes; subsidies for removing or replacing lawns; and the use of drought-tolerant turfgrass. Each respondent's current lawn (i.e., the status quo) was included as a possible choice in the choice sets, and the attributes of the current lawn were used in constructing the alternatives. Part-worth utilities for a multinomial logit model with these status quo predictors were used to analyze the choice data and provide estimates for lawn choices. The results show that low levels of subsidies to encourage lawn replacement were only a marginally significant influence on residents' landscaping decisions. Instead, the current fraction of turfgrass in the homeowner's total landscape was the strongest motivating factor driving residents' lawn choices in support of water conservation. Residents with larger proportions of turfgrass were more likely to choose landscaping changes that featured smaller percentages of lawns. Another motivating factor in residents' lawn choices was turfgrass variety, where residents with traditional varieties of turfgrass were more likely to choose landscaping options with water conserving lawns. These residents are likely candidates for policies designed to encourage reductions in lawn sizes and installation of water conserving varieties of turfgrass.

**Keywords**: water use planning; discrete choice experiment; status quo effect; water demand management; landscaping preferences; lawn; turfgrass

## 2.1. Introduction

Residential growth is stressing freshwater supplies in many communities across the world, especially those in arid regions. Accompanying this expansion is a substantial increase in lawn acreage and the amount of water required for lawn maintenance

(Robbins and Birkenholtz 2003; Alig et al. 2004). In response, water managers often develop municipal regulations and other policies pertaining to the composition and irrigation of lawns in residential landscapes to manage the long term impacts of lawn irrigation. These strategies include bylaws that restrict the percentage of turfgrass in yards (Vickers 2007; Schindler 2014), promoting the use of drought-tolerant varieties of turfgrass (Hugie et al. 2012; Yue et al. 2012), restrictions on lawn watering during summer months (Renwick and Green 2000) and payments to encourage residents to alter landscapes or compensate them after the fact (Morris et al. 1997). While these policies may promote water-efficient irrigation technologies, or water conserving types of turfgrass, or reductions in the amount of turfgrass in residential landscapes, they often focus on new landscaping installations, leaving the stock of existing lawns subject to residents' individual choices.

This paper examines residents' landscaping choices for existing residential landscapes that could lead to reductions in outdoor water use. We used an online survey with a discrete choice experiment, in which we presented hypothetical lawns to residents and explored the attributes (a characteristic or inherent feature of the lawn) that influenced their lawn selection choices. We asked respondents to repeatedly choose between a 'status quo' condition and two alternative lawns. The status quo condition (a representation of the features of their existing lawn) was generated individually for each respondent based on their answers to questions at the beginning of the survey. When presented in this way, the status quo condition is not only a potential choice, but should also inform the evaluative judgement respondents make as they choose one alternative over another. Water managers need to understand the treatment and influence of the status quo in residents' decision making, in order to develop effective water use plans and policies for existing residential landscapes. The findings from this study should enable policy makers and water managers to make more informed decisions about future water use, taking into account residential preferences for current and future lawn attributes that affect outdoor water use.

### 2.1.1. Choice experiments

We begin by examining the theoretical basis of choice experiments and how they have been used in the study of water management and policy, focusing on instances where stated preference techniques have been used to elicit residential landscaping preferences and inform the application of individualized status quo methods.

The choice experiment is a survey-based stated preference methodology pioneered by Louviere and Woodworth (1983), with several applications for water resources. For example, Haider and Rasid (2002) assessed the trade-off behaviour of the municipal residents of Thunder Bay, Ontario, Canada to determine their preferences concerning the source of municipal water supply. Willis et al. (2005) estimated benefits of improvements in water service delivery to water utility customers. Choice experiments have been used widely to assess public willingness to pay for improvements in drinking water quality (Hanley et al. 2006; Thacher et al. 2011; Latinopoulos 2014; Brouwer et al. 2015). Additionally, choice experiments have been used to investigate the non-use value of wetlands (Birol et al. 2010), domestic water demand (Birol et al. 2006), water utility customer service standards (MacDonald et al. 2005), and watering restrictions (Cooper et al. 2011).

To a limited extent, stated preference experiments have been applied to the study of lawn preferences affecting water use. Hurd (2006) presented four landscape alternatives to residents in New Mexico to identify behavioural factors affecting water conservation. Helfand et al. (2006) used a contingent choice survey to identify that residents were willing to pay more for well-designed yards featuring native vegetation than for turfgrass lawns. Yue et al. (2012) and Hugie et al. (2012) found preferences for varieties of turfgrass that require low amounts of water.

In the present study, we use a discrete choice experiment survey to elicit preferences for lawn features and status quo predictors affecting water use. We asked residents to choose between their current lawn (the status quo alternative) and two unlabeled lawn alternatives with different attributes. The current lawn presented was based on the respondent's earlier description of the attributes of their lawn, similar to the approach demonstrated in Hess et al. (2008) and Barton et al. (2010). The advantages of using the individualized status quo situation as an alternative lie in enhancing the credibility of the experiment (Glenk 2011), increasing the predictive power of the resulting analysis (Barton and Bergland 2010), and making the whole exercise more meaningful for the respondent (Rose et al. 2008).

Studies incorporating individualized status quo alternatives are relatively rare, highlighting the need to further explore the effect of status quo conditions on individual choices. Glenk (2011) found evidence of preferences for some attributes from the respondents' descriptions of current conditions. Hess et al. (2008) highlight individual preferences for increases and decreases in attribute levels away from the status quo alternative, but found these preferences were not consistent across attributes. They propose that individuals consider the relative gains and losses for different attributes when considering the status quo. More recently, Lanz et al. (2015) examined whether status quo choices reflect a preference for the attributes of the status quo or are associated with a lack of understanding between the status quo and the alternative. They found that while insufficient information and task complexity does influence status quo choices, individual status quo choices generally have a positive association with preferences for the attributes of the status quo. Taken together, these results from studies pertaining to individualized status quo alternatives suggest the need for further research into the role status quo conditions play in shaping individual choices, and the information these preferences can provide for regulators and policy makers.

Our research explores the role of individualized status quo attributes in decision making by presenting a choice experiment featuring the respondent-described status quo among the choice alternatives. It also explores heterogeneity in the respondent population by formulating part-worth utilities for a predictor-influenced multinomial logit model, which explicitly expresses heterogeneity through the respondents' personalized status quo lawn characteristics (i.e., the percentage of turfgrass in their residential landscape, variety of turfgrass, appearance of turfgrass and calculated watering costs). Not only are these variables explanatory; they were also used to individualize the choice sets each respondent evaluated. Following this framework, we provide direct evidence of the effect status quo attributes have on alternative choices.

The remainder of this paper is organized as follows. The rest of the "Introduction" section provides background information on the case study location. The "Methodology" section presents the methodology, followed by a description of the choice experiment design and selection of lawn features. A detailed description of the analytical approach to formulating status quo predictors is included. The results from the choice experiment and model-based estimates of respondent choices are described in the "Results" section. The "Discussion and Implications" section discusses how existing lawn features influence choice decisions and then outlines policy implications. Concluding remarks follow this section.

### 2.1.2. Case study location

The study site is located in the City of Kelowna, within the Okanagan Basin of British Columbia, Canada (see Fig. 2.1). Approximately 200 km long and 8,000 $km^2$ in area, the Okanagan Basin is a semi-arid valley with a climate that poses unique challenges for water managers (Cohen et al. 2006; Alexander and Robson 2007). Receiving on average 300-400 mm of rainfall annually, the Okanagan is one of the driest regions in Canada (Merritt et al. 2003). Furthermore, precipitation is limited during the peak summer water use period between June and August when temperatures frequently reach 39 $^{o}$C. Water suppliers in the Okanagan watershed rely on annual accumulation of mountainous snowpack to meet water demand (Hrasko et al. 2008). However, climate modelling suggests a likely reduction in the availability of snow water as well as drier summers, further stressing water supplies in a region with a history of droughts (Neilsen et al. 2001; Merritt et al. 2006; Duke et al. 2008; Langsdale et al. 2009).

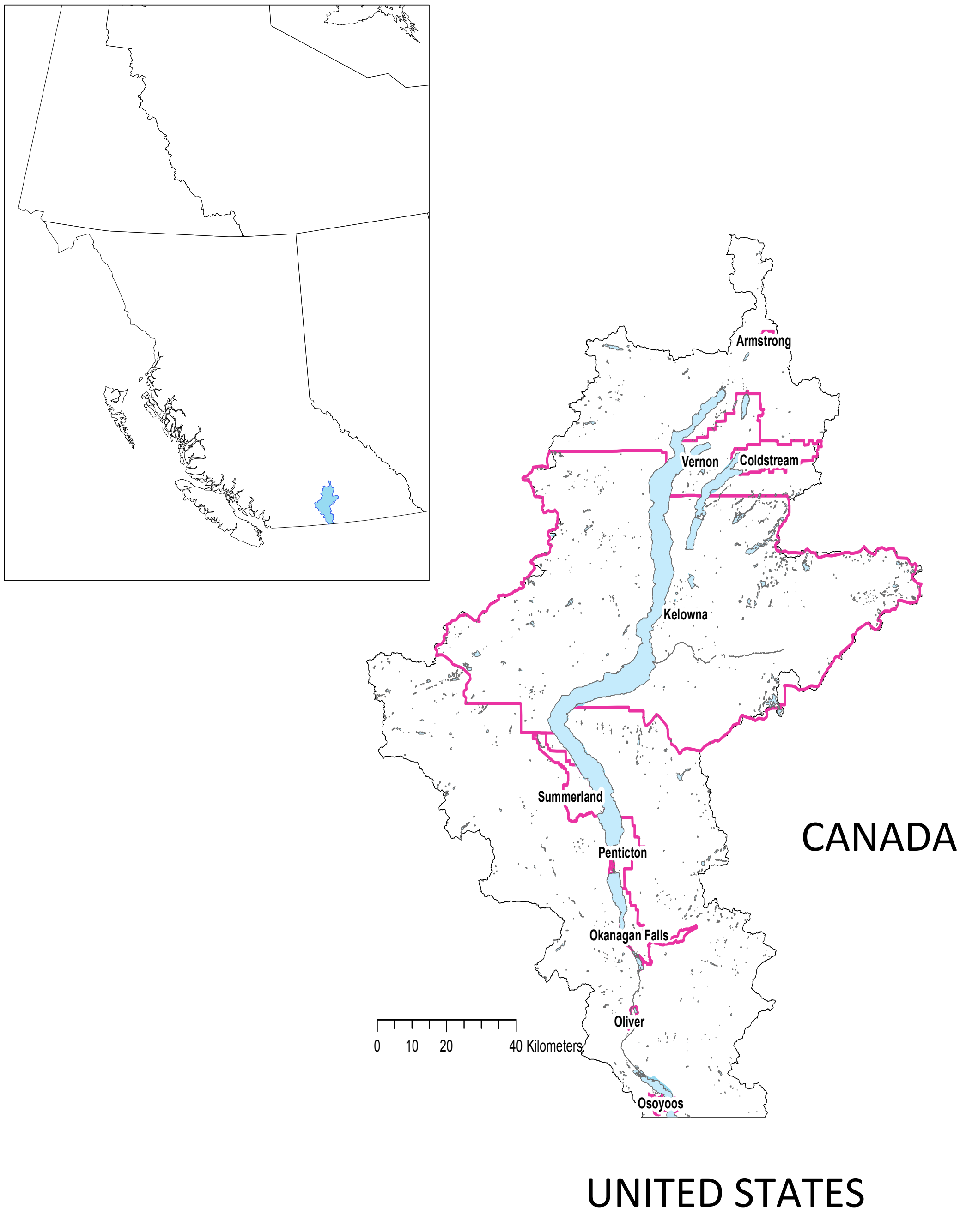


**Fig. 2.1. Map of the Okanagan Basin, British Columbia Canada**
Source: ArcGIS 10.2

Climate is one of many factors contributing to water stress in the Okanagan. Per capita share of surface water yield in the Okanagan is the lowest in Canada and urbanization is increasing demand on existing water supplies (Hrasko et al. 2008; Statistics Canada 2010; Harma et al. 2012). Currently, agriculture accounts for the majority (55%) of water use in the Okanagan (Van der Gulik et al. 2010). However, rural landscapes across the Okanagan are transitioning to urban landscapes dominated by gardens and large lawns. Residential developments in the region predominately feature low-density neighbourhoods with large lawns that require more water to maintain compared to higher density developments (Maurer 2010). Irrigating these lawns contributes to residential outdoor water use being the second largest use of water in the Okanagan (approximately 24% of all water use) (Summit Environmental 2010).

This paper explores three approaches to reducing water use for irrigating lawns in residential landscapes in the Okanagan: restrictions on lawn sizes; subsidies for removing or replacing lawns; and the use of drought-tolerant turfgrass. The effectiveness of each of these approaches in practice depends in part on the extent to which it is adopted or accepted by residents (Renwick and Green 2000; Dawadi and Ahmad 2013). As such, information about the influence of existing lawn attributes on residents' preferences will be important for Okanagan water managers as they look to manage the demand lawn irrigation places on the regional water supply.

## 2.2. Methodology

### 2.2.1. Survey design and data analysis

A custom-programmed web-based survey was developed to host the study questionnaire, which consisted of five parts occupying 24 web pages. Parts 1 and 2 welcomed respondents to the survey and asked them to provide information about their residences (e.g., residence type, number of people living in the residence, residence ownership) and current lawns. 'Warming up' questions were posed early to ensure that residents were sufficiently familiar with the choice experiment context (Krupnick and Adamowicz 2006). The data gathered from Parts 1 and 2 was used to construct individualized status quo profiles regarding the proportion of turfgrass in their yard, variety of turfgrass, appearance of their lawn during the summer months, and property size. The choice experiment was presented in part 3, followed in part 4 by questions pertaining to their perspective on water use in the Okanagan. Part 5 collected socio-demographic information and comments about the survey.

A total of 1,500 households were randomly selected from a customer list of 13,505 single-family detached households located in the City of Kelowna water utility service area. The resulting address list, after accounting for undelivered letters, provided 1,362 contacts made between April 2012 and June 2012. A modified tailored design method was followed, which included a lottery prize draw incentive for survey respondents (Dillman 2007). Residents were contacted by the City of Kelowna via a letter outlining the project and including a link to the survey website. Three weeks later, those residents who had not responded to the survey were mailed a follow-up postcard. At five weeks a final contact letter was mailed to those who had still not responded.

The survey results were compiled in an MySql database. IBM SPSS Statistics 21 was used to aggregate the results as a first step in the statistical analysis of demographics and attitudinal responses. SPSS was also used to segment the sample population by current turfgrass percentage and to perform a Pearson's chi-square test, t-tests to identify significant relationships, and one-way Analysis of Variance (ANOVA) tests to determine significant differences in the means between groups at the 95% confidence interval. The Fisher's Least Significant Difference test was used to determine significance for the ANOVA tests. Latent Gold 4.5 provided part worth utility coefficients and predictor estimates for the multinomial logit model derived following the methodology outlined in the "Choice analysis and model estimation" section. In this analysis, all attributes were effects coded, except for 'watering cost' which was coded linearly, and 'subsidy' which was coded in linear and quadratic terms to allow for the designation of different functional forms. *P* values for the resulting model are two-tailed for all tests, and z-values are reported at 1%, 5%, and 10% significance.

### 2.2.2. Design of the choice experiment

The popularity of the choice experiment approach is attributable in part to its flexibility across different research settings where the same design features apply. Respondents are asked to choose among presented alternatives with multiple attributes; the underlying theoretical assumption being that individuals will select the alternative that they believe will provide them with the greatest utility (Train 2003). Our choice experiment was operationalized through a statistical design that presented hypothetical lawn choices organized in choice sets. Each choice set included three alternatives: the respondent's current lawn (status quo alternative) and two unlabeled lawn choices (see Fig. 2.2). Each lawn alternative consisted of four attributes, plus two calculated values, and one overall context variable. A key step in designing a choice experiment is the selection of attributes that will represent a realistic framework for predicting the likely behavioural responses (Hensher et al. 2005) – in our case, whether residents will stay with their existing lawn or adopt an alternative.


**Fig. 2.2. An example choice set**

The attribute selection process involved a comprehensive review of attributes included in earlier relevant research, followed by interviews, focus groups, and expert consultation. Final attribute selection incorporated lawn features that can be found across diverse geographical regions, yet the choices of residents may be strongly influenced by the social norms of the region in which they live, so the attributes selected are to some extent context specific. Resident interviews and focus group discussions were also used to guide the description of attributes, and to ensure that the water conservation measures represented real landscaping options in the City of Kelowna. An advisory group, including representatives from regional water providers and irrigation districts, provincial and local governments, and the local academic community, made recommendations regarding attribute levels deemed appropriate for the Okanagan.

Among the attributes included in the choice experiment (Table 2.1), the proportion of turfgrass covering a resident's landscapable area is crucial because the amount of water required to maintain a residential lawn is proportional to its size. Turfgrass coverage was represented as '*% of total landscape',* rounded off to the closest 25$^{th}$, 50$^{th}$, 75$^{th}$ and 100$^{th}$ percentile and presented as 25%, 50%, 75%, and 100%. The attribute level for *% of total landscape* was described in text and visually represented as a shaded area surrounding a picture of a house (Fig. 2.2), adapting Hurd (2006).

**Table 2.1. Lawn attributes and levels**

| Attribute | Levels |
|---|---|
| % of total landscape | 25% Turf<br>50% Turf<br>75% Turf<br>100% Turf |
| Variety of turf | Traditional<br>Traditional<br>Water Conserving<br>Artificial |
| Appearance during peak of summer | Very Green<br>Mostly Green<br>More Green than Brown<br>More Brown than Green |
| One time Subsidy to reduce or replace[a] | $125<br>$250<br>$375<br>$500 |
| Price of water in 5 years | 30% more<br>60% more<br>90% more |

[a]Canadian dollars

Next, the study included respondents' preferences for three different varieties of turfgrass: traditional, water conserving, and artificial. The most common variety of turfgrass currently in the City of Kelowna, the traditional bluegrass-type, was represented at two levels in the choice sets to increase the frequency of its appearance. A water conserving variety was included to represent possible water savings attributed to drought-tolerant turfgrass species (Ervin and Koski 1998), and an artificial turf to represent zero water requirements.

The third attribute reflects the findings of previous studies, namely that perceived aesthetics could affect landscaping choices (Hurd 2006). Vickers (2007) suggests that compliance with water conservation policies limiting or restricting lawn irrigation, such as once-per-week watering rules, is influenced by individual preferences for green landscapes. In response to focus group comments that statements were easier to comprehend than colour scales, the four levels selected to represent lawn '*appearance* *during the peak of summer',* when irrigation peaks, were: 'very green', 'mostly green', 'more green than brown', and 'more brown than green'.

The fourth attribute specified payments made to residents for reducing the proportion of turfgrass or replacing traditional turfgrasses with water conserving varieties. Typically, these payments take the form of rebates based on the square footage reduction of turfgrass, as represented by programs in a number of cities including Albuquerque, New Mexico, El Paso, Texas, and Las Vegas, Nevada (Addink 2005). However, following consultation with the advisory group, we decided that area-based payments were inappropriate in the case of the City of Kelowna as it was unlikely funding would be available to support large-scale lawn replacements. Pretesting also showed that for the respondents a fixed payment was more tangible and easier to trade-off with other variables compared to area-based rebates. Based on this consultation, payment levels to reduce or replace turfgrass were set at $125, $250, $375, and $500 CAD$. A maximum level of $500 was set, as it was unlikely that higher levels would be offered by regional water utilities.

The final attribute included in the choice design pertained to the role of water pricing and its contribution to the selection of water efficient landscaping features (Willis et al. 2005; Hurd 2006; see Barton and Bergland 2010). Future water price increases were represented as a context variable labelled '*the price of water in five years'*. Levels were set at 30%, 60%, and 90% higher than current prices. The decision to represent price increases as percentages was informed by focus group discussions, which indicated that individuals tend to conceptualize price increases in percentages even when presented with dollar values.

The two lawn choices and context variable, along with their associated levels, presented 196,608 possible choice designs ($4^4$ X $4^4$ X $3^1$). We used the SAS 9.3 experimental design macro *MktEx* to reduce the number of different attribute level combinations and to produce an orthogonal main effects fractional factorial design with minimal overlapping of attribute levels (Street et al. 2005; Kuhfeld 2010). Constraints were established to exclude the possibility of generating duplicate lawn choices, and to ensure that the only colour for artificial turf was 'very green'. Thus, the number of possible combinations was reduced to 48 choice pair sets, randomized and blocked into eight different versions of six choice sets, calculated as being optimally balanced with a 95% D-efficiency.

A status quo alternative was generated for each respondent based on answers to landscaping questions posed at the beginning of the survey. Subsidy levels in the status quo alternative were always zero. To identify the level for the remaining attributes of the status quo, we asked the respondent to select the closest approximation of the % of turf covering his/her landscape, the appearance of their lawn during the peak of the summer months, and the variety of turfgrass in their lawn. In this way, the status quo condition became a true third choice, remaining consistent over all six choice sets for each respondent. Individual calculations for water use and water cost were provided for both the status quo alternative and the two lawn alternatives.

Residents participating in the study were shown a set of six choice pairs drawn from the eight blocked sets, plus their individualized status quo alternative in each choice set. For the next respondent in line, another block of six choice pairs was drawn, until the pool of blocked sets was exhausted, following which another round of set selection would commence. Respondents selected the lawn they most preferred and continued to the next set until they completed six choice sets. Prior to completing the six choice tasks, they were shown an example choice set with instructions on how to interpret the lawn attributes that were presented.

### *Individualizing water use and watering cost*

The water use and watering cost presented for each lawn alternative, including the status quo, were calculated based on the attribute levels of the percentage of turf comprising the landscape, the variety of turfgrass, appearance of the lawn during the peak of the summer, and the respondent's property size as stated earlier in the survey (see Fig. 2.3). Water use and watering costs were not attributes of the design but were included in the choice set to personalize water use and watering cost for each alternative, the purpose being to reflect the respondent's actual situation, enhance their understanding of the choice experiment, and assist them in making informed tradeoffs between alternatives. Estimates of water use and watering cost were calculated based on the following considerations.

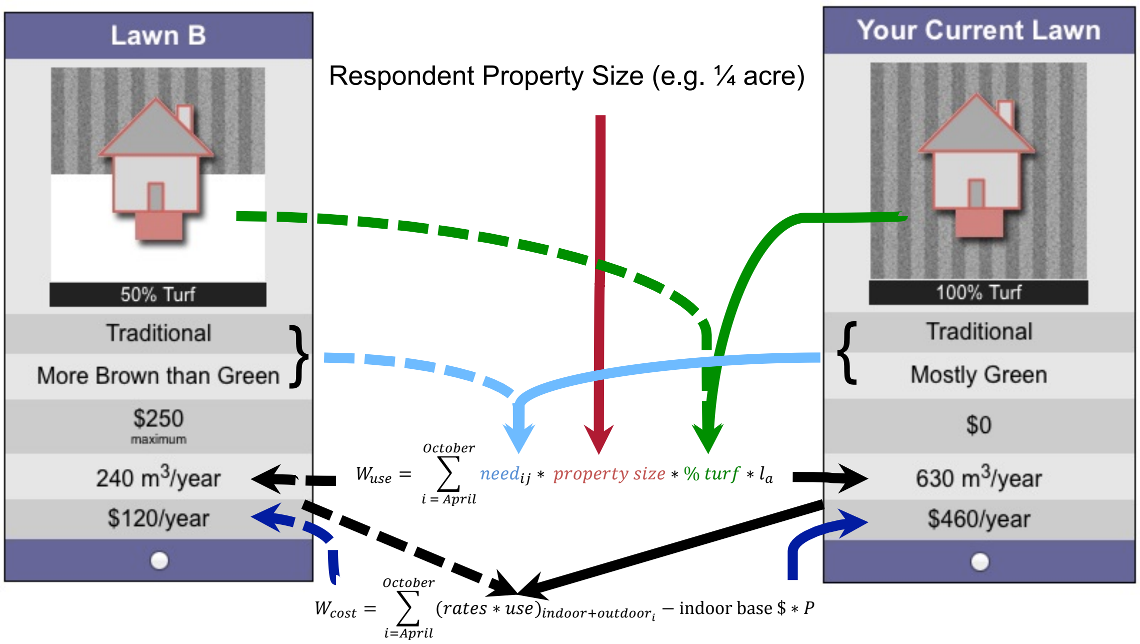


**Fig. 2.3. Visual representation of Wuse and Wcost calculations**

First, the amount of water required (mm of water per month) to maintain a healthy lawn, which will vary over the course the annual watering period (April – October), was determined based on City of Kelowna lawn irrigation guidelines (City of Kelowna). Second, the amount of water required is a function of the size of the individual respondent's property (i.e., the area) and percentage of turfgrass in the yard. Third, traditional varieties of turfgrass require more irrigation than water conserving varieties, and artificial lawns require no irrigation. Fourth, the appearance of the lawn during peak summer months was used as an indicator of irrigation levels, with a very green lawn indicating a higher than average level of irrigation, and a brown lawn indicating a lower than average level of irrigation.

Total water use $W_{use}$ (in m$^3$) was calculated as the product of water needed *need*$_{ij}$ in each month $i$ in mm of water for each variety of turfgrass $j$, property size (in m$^2$), the % of turfgrass in each yard, and a scaling factor determined from the appearance of the lawn ($l_a$ = [very green = 1.15, mostly green = 1.00, more green than brown = 0.95, more brown than green = .75]):

$$W_{use} = \sum_{i\,=\,April}^{October} \frac{need_{ij}}{1000} \times property\ size \times \%\ turf \times l_a \qquad (1)$$

Watering cost was then derived as a function of water use and water pricing. The City of Kelowna prices residential water based on an incremental four-tiered pricing structure (in CAD$): $0.32 for the first 30 $m^3$, $0.43 for the next 50 $m^3$, $0.66 for the next 45 $m^3$, and $1.31 for any amount exceeding 125 $m^3$ per monthly billing cycle. Thus, the calculation of watering cost must take into account not only the volume of water used in a given year but the amount used during each monthly billing cycle. Additionally, as City of Kelowna residents pay for indoor and outdoor water use during the same billing cycle, watering cost calculations must include indoor water use (based on a monthly average for residents in the City of Kelowna) to determine at which tier(s) lawn water usage should be priced.

To calculate water use and watering cost across the set of alternatives in the choice experiment, we developed a computer algorithm that would repeatedly calculate residential water use in a given month, apportion the water use through each of the four tiers, and estimate total water use in each tier. The sum of watering cost across the summer months $i$, along with the estimate of water price increase for the set *P*, provides the total watering cost:

$$W_{cost} = \sum_{i=April}^{October} Cost_{total_i} - Cost_{indoor\ use_i}\ \text{(for all attributes in choice set P)} \qquad (2)$$

### 2.2.3. Choice analysis and model estimation

This section provides an extended discussion of the theoretical and statistical foundation for analyzing the choice experiment data, using multinomial logit models, and including individualized predictors. To test how status quo parameters influence stated choices, we expanded the popular multinomial logit model by representing status quo parameters as choice predictors. Final model estimation was then based on the five design attributes listed in Table 2.1 with the fifth attribute, *price of water in 5 years*, substituted with an overall calculation of individualized watering cost. This substitution was motivated by low levels of significance for the levels in the design yet high significance when calculated cost, representing the price of water, was included as a parameter.

The analysis of the data is grounded in Lancaster's attribute theory of value and consumer choice (Lancaster 1966), and in random utility theory (McFadden 1974). Lancaster holds that consumers derive satisfaction not from goods themselves but from their attributes. Thus, the theory would assert that residents of the City of Kelowna do not derive satisfaction from the presence of a lawn but from its attributes.

Random utility theory postulates that choices can be modeled as a function of the attributes of the alternatives given (McFadden 1974; Train 2009). It is assumed that an individual selects the alternative *i* that has the greatest overall utility and that each attribute contributes to a part of the compound utility of the alternative. The probability $P_{ij}$ of an individual $i$ choosing an alternative $j$ equals the probability that the utility $U$ of alternative $j$ exceeds the utility of alternative $q$ (for all $q$ in a given choice set where $j \neq q$) and can be calculated as:

$$P_{ij} = \mathrm{Prob}(\mathrm{U}_{ij} > \mathrm{U}_{iq}) \qquad (3)$$

To more accurately model and understand individual preferences and choices, the overall utility $\mathrm{U}_{ij}$ of individual $i$ *choosing* alternative $j$ is viewed as a combination of the observable (or deterministic) $\mathrm{V}_i$ component of utility and the unobservable (or stochastic) $\varepsilon_i$ component of utility. Thus, utility is composed of observable and unobservable qualities that are additive and independent.

$$U_{ij} = \mathrm{V}_{ij} + \varepsilon_{ij} \qquad (4)$$

The equation above can be disaggregated further to explain $V_i$ as the sum of the utility of a good and the characteristics of an individual:

$$U_{ij} = (Z_{ij} + S_i) + \varepsilon_{ij} \quad (5)$$

where $Z_{ij}$ represents the characteristics of the good or service associated with alternative $j$ and $S_i$ represents the characteristics of individual $i$ (e.g. socio-demographic, attitudinal or psychometric). $V_{ij}$ can be expanded to further account for all attributes and socio-demographics or any other relevant variables:

$$V_{ij} = [\beta_{0ij} + \beta_{1ij}Z_{1ij} + \beta_{2ij}Z_{2ij} + \cdots + \beta_{nij}Z_{nij}] + [\beta_{aij}S_{ai} + \beta_{bij}S_{bi} + \cdots + \beta_{kij}S_{ki}] \quad (6)$$

$V_{ij}$ consists of *1* through $n$ attributes represented by $Z$ associated with the alternative $j$ individual $i$ may chose. It may also contain $a$ through $k$ socio-demographic variables of individual $i$. In this study, socio-demographic variables are included as explanatory variables (i.e., 'predictor variables'). Each $\beta$ represents the unique weight (i.e., parameter or coefficient) that accounts for the marginal utility of $Z$ or socio-demographic variable $S$. For example, $\beta_{1ij}$ is the weight associated with $Z_1$ for alternative $j$ and individual $i$. $\beta_{0ij}$ is the intercept (or alternative specific constant), a parameter not associated with any of the observed and measured attributes, and which represents the role of all unobserved sources of utility (Hensher et al. 2006).

### *Multinomial Logit Model*

Louviere (2000) and Hensher (2005) outline assumptions associated with unobservable components of utility and the principles for deriving the multinomial logit model. First, unobservable utility is allocated to each sampled individual and alternative. Second, an unobserved component exists in an unknown distribution. Third, the set of unobserved components (i.e., the error term) is independent and identically distributed across individuals. This set of assumptions is known as the independently and identically distributed condition.

Given the above principles one can express a function from utility $U_{ij}$ to ascertain a relationship between observed attributes, unobserved attributes, and stated (or observed) choice outcomes. The probability $\mathrm{P}ij$ of an individual $i$ choosing alternative $j$ from the set of $q$ alternatives is provided by:

$$\mathrm{P}_{\mathrm{ij}} = \frac{\exp V_j}{\sum_{\mathrm{h}} \exp V_q}; \quad \text{(for all q in choice set C where j} \neq \text{q)} \qquad (7)$$

Derivation of the above equation results in the multinomial logit model used as the basis for analyzing choice experiments (Adamowicz et al. 1998; Louviere et al. 2000; Hensher et al. 2005). Popular approaches, such as *a priori* segmentation or latent class segmentation, extend the multinomial model to represent heterogeneous groups; however, these approaches are not well suited for individualized status quo choice experiments. To explore status quo choices, Boxall et al. (2009) and Meyerhoff and Liebe (2009) interact the alternative specific constant, or unobserved utility associated with the status quo, with potential factors of status quo choices. This approach is limited in that it is difficult to determine whether the status quo choice reflects a preference for attributes of the status quo or a function of the choice design (Lanz and Provins 2015). In this study we expand on this method to model the probability of status quo attributes as predictors and include these in the multinomial logit model.

### *Predictors*

Predictors are included in regression models for predicting choices, but are not always featured in the design of the choice experiment. In our study, predictors were labelled lawn features that were presented in lawn alternatives but in this case represent independent attributes for the status quo alternative (i.e. % of total landscape, variety of turf, appearance during the peak of summer, and property size of the respondents' status quo). Predictors function to refine the multinomial logit model by providing characteristics of the choice set or respondent across the alternatives. Expressing the regression model as the probability individual $i$ selects alternative $j$ at replication $t$ given attribute values $z_{it}^{att}$ and predictor values $z_{it}^{pre}$ for all responses $y_{it}$, produces the following equation:

$$P\left(y_{it} = j \middle| z_{it}^{att}, z_{it}^{pre}\right) \tag{8}$$

The above specification can be adapted to provide a new regression model where the systematic component in the utility of alternative $j$ for case $i$ at replication $t$ is represented by:

$$P\left(y_{it} = j \middle| z_{it}^{att}, z_{it}^{pre}\right) = \frac{\exp\left(\eta_{j|z_{it}}\right)}{\sum_{j'=1}^{J} \exp\left(\eta_{j'|z_{it}}\right)} \tag{9}$$

where, following McFadden (1974), the term $\eta_{j|z_{it}}$ is a linear function of the alternative specific constant $\beta_j^{con}$, attribute effects $\beta_p^{att}$, and predictor effects $\beta_{jq}^{pre}$. The indices $\mathrm{p}$ and $\mathrm{q}$ refer to particular attributes and predictors. $\mathrm{P}$ and $\mathrm{Q}$ denote the total number of attributes and predictors respectively:

$$\eta_{j|z_{it}} = \beta_j^{con} + \sum_{p=1}^{P} \beta_p^{att} z_{itjp}^{att} + \sum_{q=1}^{Q} \beta_{jq}^{pre} z_{itq}^{pre} \tag{10}$$

where, for effect coding, $\sum_{j=1}^{J} \beta_j^{con} = 0$, and $\sum_{j=1}^{J} \beta_{jq}^{pre} = 0$ for 1 ≤ q ≤ Q. The resulting model structure is still efficient with respect to estimating choices, which is crucial for practical large-scale modelling analyses.

## 2.3. Results

Results presented in this paper include a description of the responses to the survey questions. In addition, the resulting part-worth utilities estimated from the predictor-influenced multinomial logit model are described and compared. A more complete description of questionnaire responses can be found in Conrad (2012).

### 2.3.1. Survey response and socio-demographics

Of the 1,362 household contacts, 690 visited the survey page on the water study website, representing a 50.7% uptake rate. The 41 respondents who did not proceed past the survey introduction were not included in the study. Protest responses were also identified and eliminated, yielding a sample size of 556 (completion rate of 80.6% and adjusted response rate of 41.0%). Of these, 399 respondents with lawns in their household landscape completed all the status quo questions and all six choice sets. This final sample represents the data set used for analysis.

Table 2.2 compares respondents' socio-demographic characteristics (age, work status, gender, income, and education) with age-adjusted 2006 and 2011 Canada census data for the City of Kelowna. The respondents included a greater proportion of residents 45 – 65 years of age in comparison with the census data, and almost one third of respondents (31.8%) were retired. Gender representation was relatively equal (47% male and 53% female) and was similar to the 2011 census data.

**Table 2.2. Socio-demographic comparison of sample population and census data for City of Kelowna (2006 and 2011)**

| Socio-Demographic Characteristics | | Sample Population (%)[a] | Census Population (%) | Adjusted Census Population (%) |
|---|---|---|---|---|
| Age (n=404) | Under 20 | 0.0 | 25.0[b] | -- |
| | 20 to 24 | 1.2 | 6.9[b] | 9.2 |
| | 25 to 34 | 7.7 | 11.9[b] | 15.9 |
| | 35 to 44 | 15.1 | 11.4[b] | 15.2 |
| | 45 to 54 | 29.5 | 14.4[b] | 19.2 |
| | 55 to 65 | 27.5 | 12.4[b] | 16.5 |
| | 65 or over | 19.1 | 18.0[b] | 24.0 |
| Retired (n=399) | Yes | 31.8 | N/A | |
| | No | 68.2 | N/A | |
| Gender (n=399) | Male | 47.0 | 48.0[b] | |
| | Female | 53.0 | 52.0[b] | |
| Income CAD$ (n=373) | Median | \$80,000 to \$99,000 | \$48,859[c] | |
| Education (n=396) | Less than high school | 1.3 | 19.8[c] | |
| | Completed high school | 23.5 | 29.6[c] | |
| | University, trades, non-university certificate/diploma | 75.3 | 50.6[c] | |

[a]Survey was exclusive to individuals 18 years of age and older.
[b]Source: 2011 Census data, Government of Canada.
[c]Source: 2006 Census data, Government of Canada.

### *Status Quo Conditions*

The majority of respondents (62.2%) in the study's sample reside on properties of greater than 0.15 acres (0.061 hectares) and less than 0.25 acres (0.103 hectares) in area; 23.3% reside on larger properties between 0.25 acres (0.103 hectares) and 0.5 acres (0.203 hectares) in area. Respondents were asked to consider the amount of turfgrass covering the area of land surrounding their home, driveway and patio. A combined majority of the respondents' household landscapes contain approximately 75% turfgrass (38.1%) or 50% turfgrass (37.3%), while about one quarter (23.3%) have yards containing approximately 25% turfgrass (Fig. 2.4). Very few respondents (1.3%)

have yards containing 100% turfgrass. Traditional varieties of turfgrass (e.g., Kentucky blue grass or ryegrass) comprise a significant majority (95.5%) of the respondents' lawns compared to water conserving varieties (4.5%) or artificial lawns (0%). During summer months, the majority of the respondents irrigate their lawns to maintain a 'mostly green' (38.6%) or 'more green than brown' (47.1%) appearance. Just 10.8% of respondents maintain a 'more brown than green' lawn.

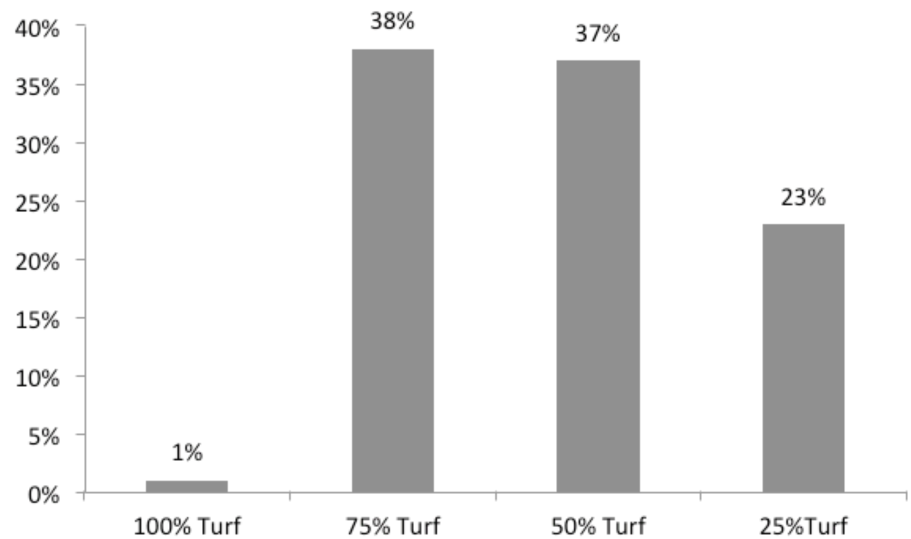


**Fig. 2.4. Proportion of lawn (turfgrass) cover in respondents' yards**

Examining the distribution of other lawn features against the proportion of turf shows no significance ($p > .05$) for property size (Fig. 2.5) or turfgrass variety (Fig. 2.6). The p-values for these two chi-square tests were greater than 0.05, indicating that the null hypothesis should not be rejected at the 95% confidence interval. However, a Pearson's chi-square revealed a statistically significant correlation between the proportion of turf and lawn appearance during peak summer months $X^{(2)}$ (6, n=399) = 15.168, p = 0.019 (Fig. 2.7). A 'very green' appearance is associated with a smaller proportion of turf, a 'more brown than green' appearance with a larger proportion of turf.

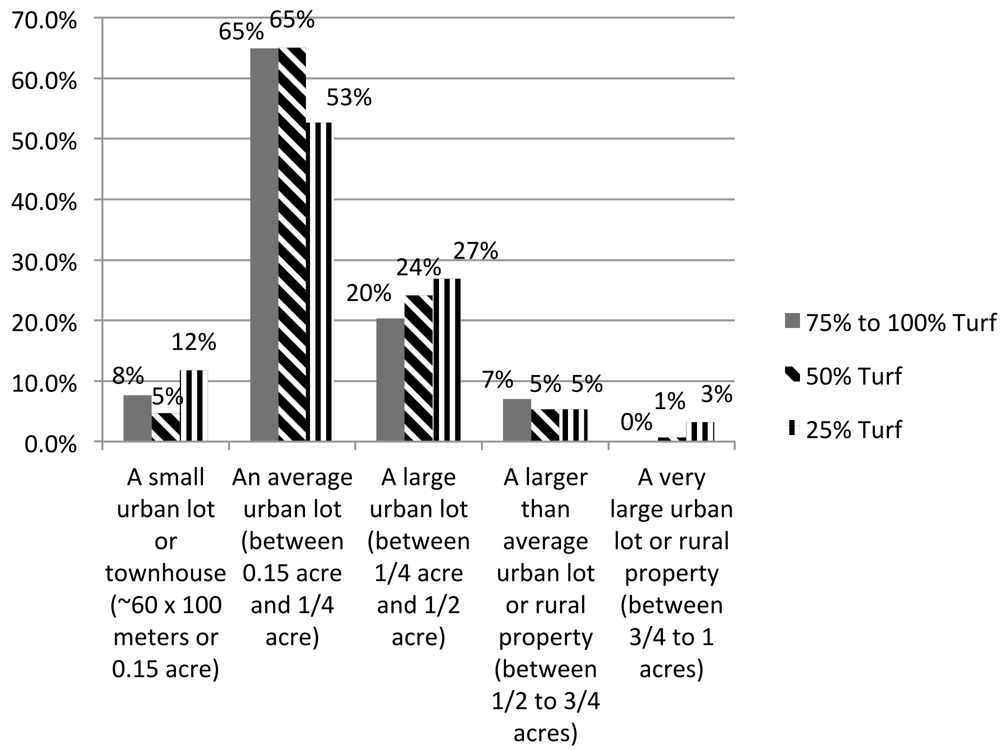


**Fig. 2.5. Property sizes by proportion of turfgrass**
Pearson's chi-square=13.504, p=0.096.

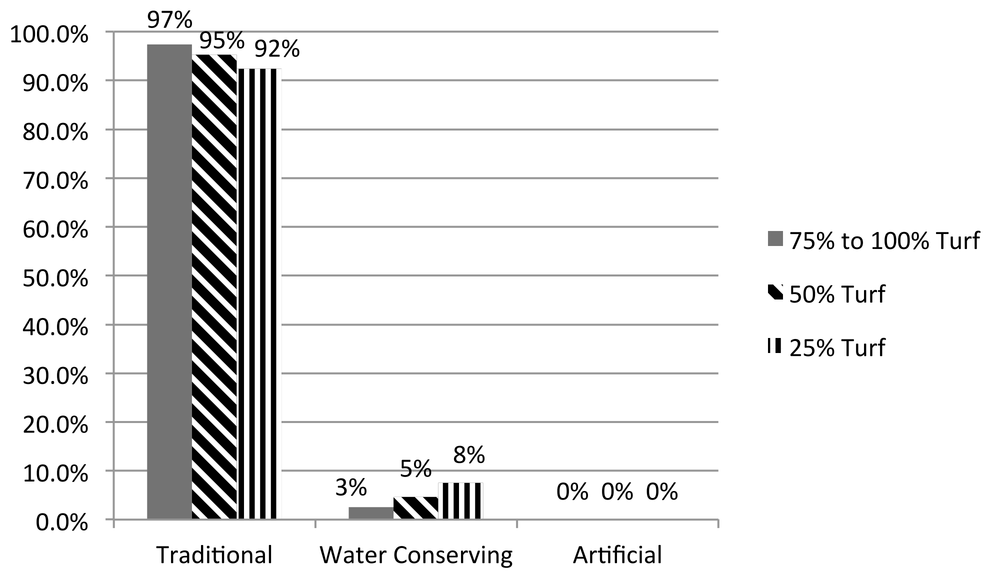


**Fig. 2.6. Lawn varieties by proportion of turfgrass**
Pearson's chi-square=3.380, p=0.184.

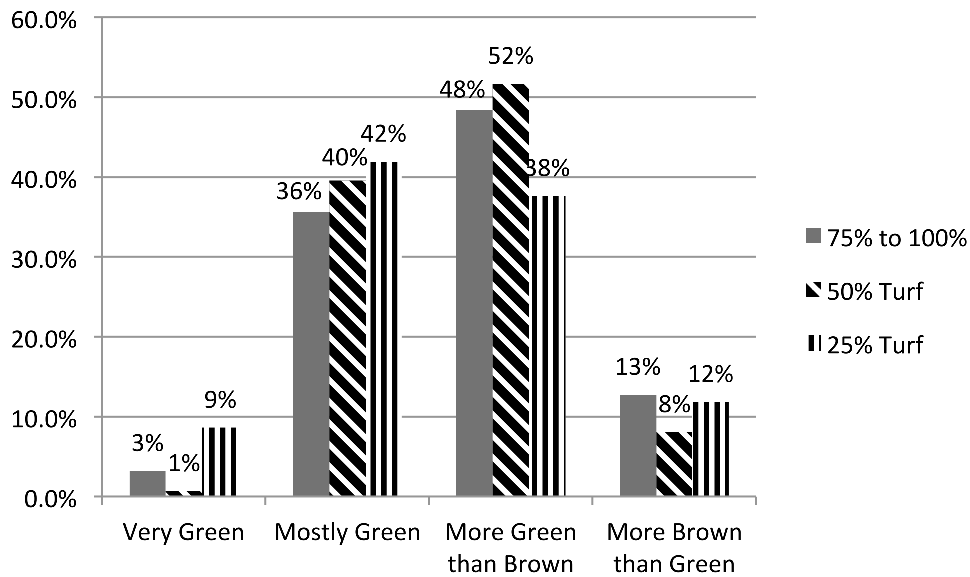


**Fig. 2.7. Appearance of lawn during the peak of summer by proportion of turf**
Pearson's chi-square=15.168, p=0.019.

## 2.3.2. Choice model results

Choice responses from the 399 respondents provided data for the multinomial logit model with predictors shown in Table 2.3. Model selection was based on maximizing the overall fit for main effects with an estimated McFadden pseudo-Rho$^2$ of 0.2528. Part worth utility estimates for effect-coded *subsidy* levels were replaced with linear and quadratic substitutes to improve model performance. Likewise, part worth utility estimates for the context attribute *price of water in 5 years* were not found to be significant and were replaced with individualized *watering cost* values in the resulting model. The quadratic part worth utility estimates for the attribute *subsidy* do indicate a small, at $p < .10$, influence on residents' landscaping choices, and *watering cost* was significant at $p < .01$.

**Table 2.3. The multinomial logit model with predictors[a]**

| Attribute | Attribute Level | Coef[b] | St.Er[b] | z-value[d] | Wald (p-value) |
|---|---|---|---|---|---|
| *Alternative Specific Constant* | Lawn A | -0.215 | 0.184 | -1.169 | 9.70 x10-5 |
| | Lawn B | -0.443 | 0.185 | -2.395** | |
| | Current Lawn | 0.658 | 0.155 | 4.247*** | |
| *% of total landscape* | 100% Turf | -1.356 | 0.113 | -11.988*** | 2.40 x 10-41 |
| | 75% Turf | -0.090 | 0.074 | -1.209 | |
| | 50% Turf | 0.781 | 0.068 | 11.548*** | |
| | 25% Turf | 0.665 | 0.079 | 8.464*** | |
| *Variety of turf* | Artificial | -0.239 | 0.107 | -2.228** | 2.10 x 10-12 |
| | Traditional | -0.180 | 0.070 | -2.581*** | |
| | Water Conserving | 0.419 | 0.068 | 6.162*** | |
| *Appearance during peak of summer* | Very Green | -0.188 | 0.077 | -2.426** | 2.30 x 10-7 |
| | Mostly Green | 0.293 | 0.069 | 4.228*** | |
| | More Green than Brown | 0.172 | 0.066 | 2.610*** | |
| | More Brown than Green | -0.277 | 0.072 | -3.836*** | |
| *Subsidy (Linear)[e]* | | -0.002 | 0.017 | -0.144 | 0.890 |
| *Subsidy[e] (Quadratic)* | | 0.064 | 0.039 | 1.650* | 0.099 |
| *Lawn Watering Cost (Linear)[e]* | | -0.0008 | 0.0002 | -3.8294*** | 1.3 x 10-4 |

[a] $Rho^2$=0.2528
[b] Coefficient
[c] Standard Error
[d] *** indicates significance at 1 % level, ** at 5 %, and * at 10 %
[e] per $

**Table 2.3. continued....**

| Attribute | Attribute Level | Coef | St.Er | z-value | Wald (p-value) |
|---|---|---|---|---|---|
| *% of total landscape in status quo Predictors* | Lawn A | 0.440 | 0.223 | 1.976** | $3.10 \times 10^{-43}$ |
| *100% Turf* | Lawn B | 0.098 | 0.231 | 0.426 | |
| | Current Lawn | -0.538 | 0.210 | -2.559*** | |
| | Lawn A | 0.093 | 0.089 | 1.046 | |
| *75% Turf* | Lawn B | 0.326 | 0.091 | 3.597*** | |
| | Current Lawn | -0.419 | 0.082 | -5.134*** | |
| | Lawn A | -0.142 | 0.092 | -1.547 | |
| *50% Turf* | Lawn B | -0.017 | 0.093 | -0.180 | |
| | Current Lawn | 0.159 | 0.082 | 1.939** | |
| | Lawn A | -0.391 | 0.106 | -3.685*** | |
| *25% Turf* | Lawn B | -0.408 | 0.109 | -3.754*** | |
| | Current Lawn | 0.799 | 0.089 | 8.957*** | |
| *Variety of turf in status quo Predictors* | Lawn A | 0.090 | 0.104 | 0.862 | 0.024 |
| | Lawn B | 0.127 | 0.107 | 1.182 | |
| *Traditional* | Current Lawn | -0.217 | 0.079 | -2.738*** | |
| | Lawn A | -0.090 | 0.104 | -0.862 | |
| *Water Conserving* | Lawn B | -0.127 | 0.107 | -1.182 | |
| | Current Lawn | 0.217 | 0.079 | 2.738*** | |

**Table 2.3. continued....**

| Attribute | Attribute Level | Coef | St.Er | z-value | Wald (p-value) |
|---|---|---|---|---|---|
| *Appearance during peak of summer status quo Predictors* | Lawn A | -0.049 | 0.170 | -0.287 | 0.200 |
| *Very Green* | Lawn B | -0.103 | 0.174 | -0.593 | |
| | Current Lawn | 0.152 | 0.138 | 1.103 | |
| | Lawn A | -0.126 | 0.079 | -1.602 | |
| *Mostly Green* | Lawn B | 0.105 | 0.079 | 1.332 | |
| | Current Lawn | 0.021 | 0.064 | 0.328 | |
| | Lawn A | -0.029 | 0.075 | -0.383 | |
| *More Green than Brown* | Lawn B | 0.063 | 0.076 | 0.830 | |
| | Current Lawn | -0.034 | 0.062 | -0.551 | |
| | Lawn A | 0.204 | 0.098 | 2.081** | |
| *More Brown than Green* | Lawn B | -0.065 | 0.102 | -0.639 | |
| | Current Lawn | -0.139 | 0.085 | -1.640 | |
| *Property Size Status quo Predictors* | Lawn A | -0.041 | 0.164 | -0.252 | 0.130 |
| *Small Urban Lot* | Lawn B | 0.015 | 0.162 | 0.092 | |
| *(0.06 hectares)* | Current Lawn | 0.026 | 0.134 | 0.195 | |
| | Lawn A | -0.090 | 0.130 | -0.693 | |
| *Average Urban Lot* | Lawn B | 0.055 | 0.129 | 0.427 | |
| *(between 0.06 and 0.10 hectares)* | Current Lawn | 0.035 | 0.102 | 0.345 | |
| | Lawn A | -0.157 | 0.138 | -1.138 | |
| *Large Urban Lot* | Lawn B | 0.064 | 0.137 | 0.471 | |
| *(between 0.10 and 0.20 hectares)* | Current Lawn | 0.093 | 0.101 | 0.919 | |
| | Lawn A | 0.298 | 0.168 | 1.774* | |
| *Larger than Average Urban Lot or Rural Property* | Lawn B | 0.079 | 0.175 | 0.450 | |
| *(between 0.20 and 0.30 hectares)* | Current Lawn | -0.377 | 0.141 | -2.684*** | |
| | Lawn A | -0.010 | 0.463 | -0.021 | |
| *A Very Large Urban Lot or Rural Property* | Lawn B | -0.213 | 0.461 | -0.463 | |
| *(between 0.30 and 0.40 hectares)* | Current Lawn | 0.223 | 0.322 | 0.694 | |

The multinomial logit model reveals that all other main-effect attributes have a significant impact on resident choices. The alternative specific constant for Lawn A, Lawn B, and the status quo reveals a preference for the status quo alternative. Parameter estimates for the *% of turfgrass* in the total landscapable area show a preference for lawns that make up a smaller percentage of household landscapes. Residents are more likely to select lawns that represent 25% or 50% of the total landscapable area. Residents also express strong negative preference for household landscapes featuring turfgrass only (i.e., 100% turfgrass covering the landscapable area). If the lawn alternative features a water conserving variety of turfgrass, residents are much more likely to choose the alternative over lawns with traditional or artificial varieties. Part worth utility estimates for both traditional and artificial varieties are negative and nearly equal. Resident preferences for lawn appearances are represented by an inverted *U* shape, with residents less likely to choose lawn appearances that are very green or more brown than green. Residents are most likely to choose lawn alternatives with lawns that are mostly green during the peak of summer. Overall *watering cost* is a factor in landscaping choices with residents less likely to choose lawn alternatives with higher irrigation costs. Yet low levels of subsidies to encourage lawn replacement were only a marginally significant influence on residents' landscaping decisions.

Predictor estimates representing the status quo contribution to the probability of an individual choosing an alternative (i.e., Lawn A or Lawn B) or the status quo are also shown in Table 2.3. Each predictor variable is presented separately for each attribute level, and for each of the three choice alternatives. Wald values indicate that the appearance of a resident's existing lawn is not likely to influence whether the resident would choose the status quo option or one of the two lawn alternatives. Similarly, the significance of the *Property Size Status quo* varied across property sizes, suggesting that property size does not influence lawn choices, with one exception: respondents with very large urban lots (i.e. properties greater than ¾ acre, 0.303 hectares, but smaller than 1 acre, 0.405 hectares) are less likely to choose the status quo option.

Significance was found for the predictors *% of total landscape in status quo* and *Variety of turf in status quo* across all attribute levels suggesting that these two predictors influence the probability that a resident would choose an alternative. Coefficient values for these predictors also refine which residents would likely choose their status quo alternative. Residents with larger proportions of lawn in their landscape (i.e., 75% or 100%) are more likely to choose a new alternative over the status quo. Conversely, residents with smaller proportions of lawn in their landscape (i.e., 25% or 50%) are more likely to choose the status quo over an alternative. The predictor estimates for lawn variety suggest that residents with traditional varieties of turfgrass will more likely choose an alternative lawn while those with water conserving varieties will more likely choose to stay with their current lawn.

## 2.4. Discussion and Implications

This study examines status quo predictors in a choice experiment involving individual landscape choices that affect water use. Given the recent growth in the use of choice experiments to support water management plans and associated regulations, differentiating the contribution of status quo factors from those of hypothetical alternatives is important. Indeed, from a management perspective, plans that do not consider the impact of such factors could miss opportunities to target incentives and other programs toward residents with particular status quo conditions.

From a methodological perspective, this study includes a number of innovative features designed to investigate the influence of existing lawn attributes on choices about lawn alternatives that could conserve water. First, the survey instrument elicits existing lawn attributes in order to describe the status quo, building on approaches used by Hurd (2006) and Hess et al. (2008). Second, the presentation of the status quo and other alternatives include individualized information on water use and water cost for each possible choice, derived from the information provided by the respondents about their lawns, along with the hypothetical attributes of the alternatives and the prices and water quantities specified in the experimental design. Third, the analysis includes a derivation of part-worth utility estimates from lawn attributes and status quo conditions as predictors of future choices.

Our findings confirm the status quo bias observed in Samuelson et al. (1988) in that we find our respondents express a preference for their existing lawns. Yet contrary to Samuelson et al. (1988) our findings illustrate that the bias is dependent on individuals' preferences for particular status quo attributes (e.g. existing lawn features). When we include status quo predictors in the analysis, the resulting model suggests that residents with smaller lawns are much more likely to choose the status quo regardless of the options presented. Likewise, the model illustrates that residents that have already made an investment in water conserving varieties of turfgrass are more likely to choose the status quo alternative than are those residents with household landscapes featuring traditional varieties of turfgrass. Conversely, our model suggests residents with medium-to-larger lawn sizes are more likely to choose landscaping alternatives, especially those that feature water conserving varieties of turfgrass and a reduction in the total area of turfgrass.

Taken together, these results show that preferences for attributes that describe the status quo play a role in explaining choices among the status quo and various alternatives. Importantly, the combination of these preferences and the relevance of alternative attributes may help to explain the satisfaction individuals have with their current service or good and how they are affected by the proposed alternative. From this perspective, the results provide further evidence to support the broad application of discrete choice experiments to elicit consumer preferences, and specifically as a tool to account for customer preferences in regulated sectors. More generally, in those cases where the status quo is a viable option from a policy perspective, the inclusion of individualized status quo alternatives is important if respondents are not to be constrained in selecting a preferred alternative.

With regard to landscape design, the results show that status quo choices do not necessarily reflect an overall bias for the status quo, but rather a preference for specific status quo attributes. Including the attributes of the status quo, as described by the respondents, likely improves a respondent's ability to evaluate the alternatives, making a comparison between status quo and non-status quo options more feasible. The individualized status quo design presented in this paper offers an option to evaluate the preferences for status quo attributes independently or concurrently with alternative attributes.

From a water use planning perspective, it is important to provide residents with a scenario of the status quo and alternatives that reflects the possible evolution of landscaping options as well as those that present opportunities to realize a reduction in water use and water cost. By including a description of water use and watering cost across all alternatives, the study provided a status quo condition that was not always the lowest cost option.

### *Management implications*

Quantifying the influence of status quo conditions provides valuable information for explaining preferences within a choice context, and quantifying preferences for lawn attributes in residential landscapes can inform policy actions to advance the management goal of reduced water use (City of Kelowna 2009). For example, the preference expressed by City of Kelowna residents for smaller proportions of turf in their yards suggests that lawn size is a reasonable policy target for local and regional water conservation strategies. City of Kelowna homeowners with larger proportions of turf in their yards may be willing to make water conserving landscaping choices. However, Conrad (2012) found that price and time were considerable barriers to voluntary reductions in lawn size. Financial subsidies are one possibility that could be used by policy makers to prompt action, but in our experiment the subsidies had only a small influence on landscaping choices. Another possible policy measure that could prompt action would be to provide site specific information to homeowners about the potential savings in watering costs if they shifted to water conserving landscapes. A third possible policy measure would be command and control regulation, such as a requirement that turfgrass areas be limited to 25% or 50% of the total landscape area.

## 2.5. Conclusion

This study of residents in one city in the Province of British Columbia highlights the importance of understanding preferences about existing lawn characteristics when developing policy options for water conservation in residential areas. Despite representing a single case study, the theoretical and procedural insights drawn from the study have broad value. The results show that the current fraction of turfgrass in the homeowner's total landscape was the strongest factor in residents' lawn choices. Existing homeowners with larger proportions of turfgrass were more likely to choose landscaping changes that featured smaller percentages of lawns whereas homeowners with smaller proportions of lawn were less likely to choose landscaping changes even if those changes reduced the amount of water required to maintain the lawn. This study has shown that for residents, the attributes of their existing lawns, and not just the attributes of the alternative, contribute to whether residents would likely make landscaping alterations.

From a methodological perspective, the inclusion of status quo predictors in the multinomial model provides new information about how status quo bias operates in influencing choices about alternatives. For water managers, the results provide unique insights into how residential choices will affect the outcome of any well-intended landscape policy. Further, this paper presents a method by which water managers can assess the potential of landscaping programs that target outdoor water use and, ultimately, be more likely to succeed in preparing water use plans that see reductions in lawn irrigation requirements.

## 2.6. Acknowledgements

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# Chapter 3.

# Profiling farmers' preferences about drought response policies using a choice experiment in the Okanagan Basin, Canada

*This chapter has been submitted to Water Resources Management as Conrad, S., Rutherford, M., and Haider, W., "*Profiling farmers' preferences about drought response policies using a choice experiment in the Okanagan Basin, Canada*". I authored the majority of the text in this paper. I additionally designed and led the fieldwork for this research, conducted the analyses, and prepared the tables and figures for this paper.*

## Abstract

Farmers play a crucial role in water management during water shortages, yet little is known concerning the preferences farmers have for various options in drought response planning. In this paper we demonstrate and discuss the use of a discrete choice experiment to investigate the preferences of farmers about options for drought response policies in the Okanagan region of British Columbia, Canada. In the choice experiment, three policy instruments were varied across possible drought response plans: mandatory water reductions, priority re-allocations of available water, and opportunities for water trading. Results show that participating farmers, as a whole, are more likely to accept drought response plans with moderate levels of mandatory water reductions, water allocations according to the sensitivity of crops to water loss, and opportunities for water trading between farmers. When analyzed according to the primary crop cultivated, preferences differ. Grape growers are more likely to prefer drought response plans with opportunities for water trading between all water users, whereas ranchers are more likely to prefer drought response plans that feature high levels of mandatory water reductions. We contrast our findings with preconceptions about farmers' preference's concerning water use policies in the Okanagan. We also discuss broader implications of the research, including the usefulness of choice experiments for informing the development of effective drought response policies.

**Keywords**: drought response plans; discrete choice experiment; farmer preferences; water shortage; water trading; water allocation

## 3.1. Introduction

Drought response plans endeavour to mitigate the impacts of short-term water shortages by temporarily supplementing, reducing or reallocating the amount of water available to users. In many settings, however, the options for supplementing water supply during drought are limited, costly or undesirable. Instead, water managers must choose among a variety of voluntary or mandatory policy instruments designed to reduce or reallocate water use. For example, drought response policies may encourage conservation or reuse of water, impose a percentage reduction in the amount of water available to all users, grant priority to particularly important uses, or establish markets for water trading (British Columbia Ministry of Environment 2010a; Estrela and Vargas 2012; Kiem 2013). Unfortunately, in choosing among such options water managers often have little empirical information about the preferences of water users concerning the available policy instruments, or whether a particular instrument will even be perceived by users as acceptable. Instead, water managers often formulate policies based on their own uncertain and sometimes inaccurate assumptions about the perceptions and preferences of water users.

In this paper we demonstrate and discuss the use of a discrete choice experiment to investigate the preferences of farmers about various options for drought response policies in the Okanagan region of British Columbia, Canada (BC). Many of these farmers are among the more senior water license holders in this region, and understanding their preferences is an important prerequisite for the development of an effective and acceptable strategy for responding to drought. The choice experiment included three policy instruments, presented as attributes of a potential drought response plan: mandatory percentage reductions in supply; granting particular types of crops priority in water allocation; and providing opportunities for water trading. Farmers were asked to choose between scenarios offering various combinations of these policy instruments under specified conditions concerning the probability of a water shortage and the predicted impact of each scenario on watershed stream health.

By identifying the preferences of water users about potential drought policies *a priori*, our results offer important information to water managers and provincial regulators about the feasibility of various options for drought response planning in the Okanagan region and more broadly in BC. Our research also demonstrates a method for profiling water users' policy preferences that can be applied in any setting where information about those preferences could contribute to better water management policies.

### 3.1.1. Drought response policy instruments

In this section, we describe the policy instruments that we included in the choice experiment and provide examples of their use in practice. Drought response plans often incorporate a mix of several policy instruments. Our choice experiment similarly presented participants with proposed drought response plans that included various combinations and settings of these instruments.

The first policy instrument included in the choice experiment was *water trading*. Water trading, or the voluntary exchange of water rights in a water market, can improve agricultural water use efficiencies by encouraging the transfer of water rights to users with the highest marginal return (Rosegrant et al. 1995; Dridi and Khanna 2005; Heaney et al. 2006; Janmaat 2010). Farmers in northern Victoria, Australia, for instance, routinely use water trading to manage short term water shortages (Bjornlund 2006). The effectiveness of water markets in increasing water efficiency has also been demonstrated in Brazil, the United States and Europe (Gómez et al. 2004; Ward et al. 2006; Campos and Studart 2006).

The second policy instrument in the choice experiment was *mandatory reduction* in water supply. In many jurisdictions drought response policies impose mandatory reductions on agricultural water use during droughts, on the presumption that with careful planning farmers have the capacity to absorb moderate reductions, depending on the type of crop they grow (Fereres and Soriano 2006). Mandatory reductions have been effectively applied to manage the impact of drought in Texas, California, and Colorado (Shaw and Maidment 1987; Renwick and Green 2000; Kenney et al. 2004).

The third policy instrument included in the choice experiment was *priority reallocation* of water among farmers during periods of drought, either based on the type of crop grown or proportional distributions[1]: a system of proportioning the available water on the basis of the maximum quantity originally allocated in each agricultural water

[1] For an example of proportional water allocation see He et al. (2012)

license or property allotment. This policy instrument stems from the argument that fixed licensing systems are inefficient and may allocate scarce water to grow low value or surplus crops (Colby 1990). An optimal water allocation system would see water allocated to either high value crops (Dinar and Mody 2004), or crops that are more sensitive to water loss (Pereira et al. 2002).

Each of these policy instruments has the potential to be a useful component of a drought response plan. However, the effectiveness of both mandatory and voluntary water policies depends in part on the attitudes of water users toward the proposed policy instrument (Easter et al. 1998). For instance, economic and production concerns, as well as farmers' views about water entitlements, have been identified as barriers to both water markets and mandatory reductions in some settings (Gaffney 1997; Tisdell and Ward 2003). Mandatory water use reductions may also be perceived as negatively affecting the ability of farmers to bring crops to harvest. Farmers have expressed distrust of water markets, and the apprehension that such markets may lead to a decline in agricultural production as water is transferred to other uses (Randall 1981; Tregarthen 1983). Research on water policy in BC has noted that farmers and representatives of environmental non-government organizations have expressed concerns about water trading (Brandes et al. 2008; Janmaat 2011). Although it may be possible to impose drought response policies despite negative perceptions or lack of acceptability among water users, such conditions may make it difficult for water managers to adopt a specific policy instrument, or may lead to implementation problems after the instrument has been adopted. Thus, despite demonstrated success in one setting, a particular policy instrument may be more problematic in another setting where it does not align with the preferences of water users.

### 3.1.2. Case study setting

The study site is located in the Okanagan region of south-eastern BC, a region characterized by susceptibility to seasonal water shortages (Fig. 3.1). The Okanagan relies on winter snowfall for the majority of its annual water supply, as summers are typically warm and dry (Merritt et al. 2006). The climate is well suited for farming, and agriculture dominates land use in the region (Hrasko et al. 2008; Van der Gulik and Neilsen 2008). Agriculture represents the single largest use of water in the Okanagan watershed and water withdrawals for this use are expected to increase as climate change introduces longer growing seasons (Summit Environmental 2010; Van der Gulik et al. 2010). Over the past century the depth and duration of snowpack in the region has declined and winter maximum temperatures have increased by 2.0 °C from 1916 to 2000 (Cohen and Kulkarni 2001; Taylor and Barton 2004). Meanwhile, the warm and dry summer climate has spurred economic and population growth increasing the demand for high quality water (Hrasko et al. 2008). In the past, water managers mainly used surface storage to moderate droughts and meet growing water demand (McNeill 2004), but there has been increased attention in recent years to the development of new strategies for reducing water use and allocating scarce water during expected water shortages (Harma et al. 2012).

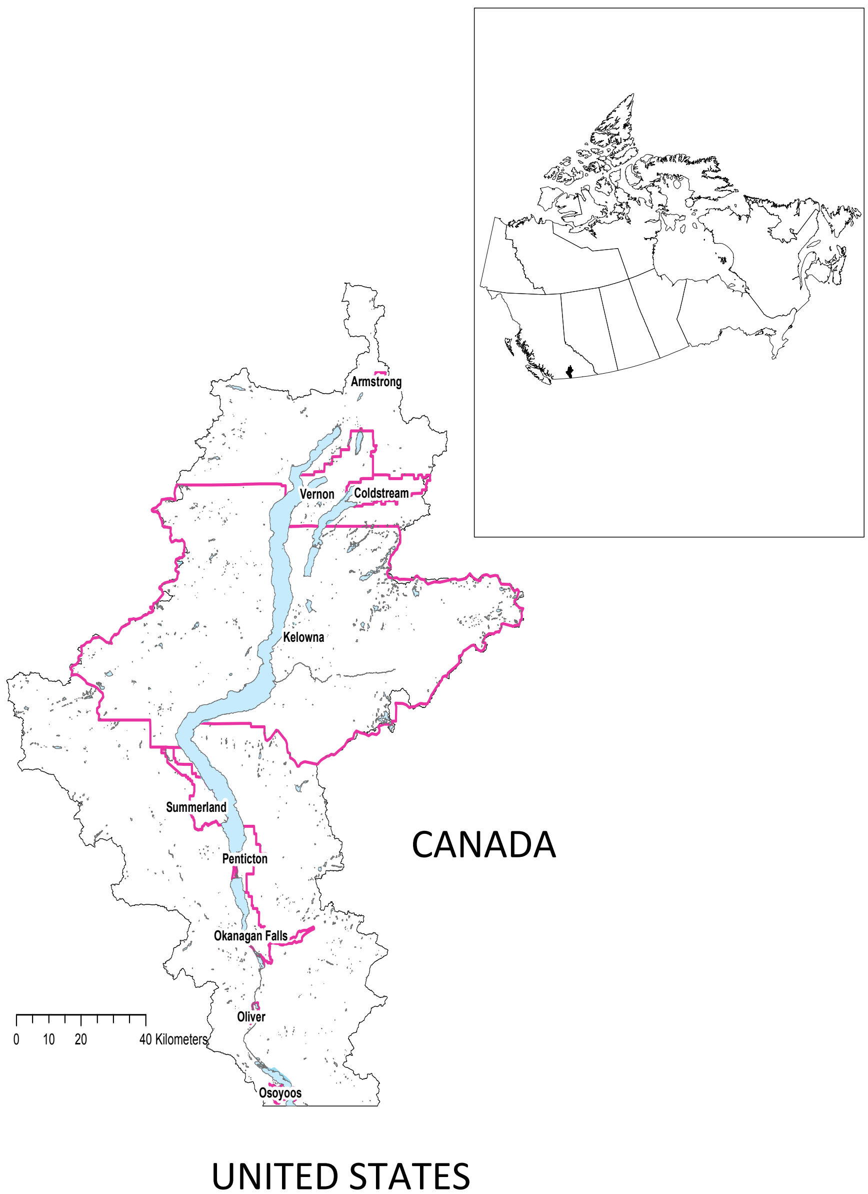


**Fig. 3.1. Map of the Okanagan Basin, British Columbia Canada**
Source: ArcGIS 10.2

Freshwater management in BC has operated for more than a century under a provincial water licensing system that allocates priority among licences according to the doctrine of prior appropriation. Under this system, an individual wishing to divert water for beneficial uses must obtain a water license from the province, and the license gives "first in time, first in right" priority over licenses acquired at a later time. The principle of prior appropriation originally functioned in western provinces and states as a simple and seemingly practical strategy for water allocation, giving at least the illusion of a workable rule in times of water shortages (Tarlock 2001). However as water sources have become fully allocated or even over-allocated, the application of priority-based doctrines can create conflict between senior and junior license holders (Rood and Vandersteen 2009), especially during periods of drought, when a senior license holder may receive their full entitlement while a junior license holder receives a reduced amount or none. In addition, community values have evolved, and there is now more importance attached to maintaining instream flow and providing for non-human uses. Satisfying these new societal demands concerning water requires new forms of governance and policies for allocating water (Tarlock 2001).

In recognition of the need to modernize its water laws, the BC government enacted a new *Water Sustainability Act* in 2014, following a lengthy period of public consultation during which provincial officials debated a variety of new policy instruments, including area-based water regulations, agricultural water reserves to ensure water for food production, water trading, and deviation from prior appropriation principles in times of drought (British Columbia Ministry of Environment 2010b). Although the new legislation does not include explicit provisions for water trading, it does allow for local water sustainability planning processes, drought plans, adjustments to existing water allocations, and dedicated water reserves for agricultural purposes (Curran 2014). The possibility of new water allocation regimes and increased local control over water planning associated with this reform of water legislation in BC highlighted the need in the Okanagan region for better information about the preferences of water users, and particularly farmers, concerning alternative policy instruments.

Several previous studies have sought to involve farmers in research on managing water scarcity in the Okanagan. Schorb (2006) interviewed farmers in the region to identify preferred agricultural practices for adapting to water shortages and the factors that farmers believed should be included in agricultural policy. Schorb concluded that growers did not perceive the need to use water efficiently for its own sake but she noted that deficit irrigation could lead to lower water consumption (deficit irrigation involves optimizing water use by exposing crops to some degree of water stress with the expectation that any loss in production is offset by gains in being able to divert water to other crops). Langsdale et al. (2009) included farmer groups in the development of a systems dynamic model to enhance dialogue for developing water management plans in the Okanagan region. They noted that even under projected rapid residential growth, agriculture would remain the predominant water user in the Basin, partly due to climate change increasing total agricultural demand. Recently, Janmaat (2010) argued for water markets in the Okanagan as a means of improving agricultural efficiency during water shortages.

Our study builds on this previous research by including farmers in the formulation process of policy design for drought response planning in the Okanagan. Surveys employing stated preference techniques can be useful in evaluating hypothetical policies where revealed preference data are not available because the policies have not previously been attempted. Choice experiments are an excellent technique for eliciting stated preferences, as respondents are required to make explicit trade-offs between alternatives. The results provide a rich description of respondents' preferences based on the attribute trade-offs reflected in their choices (Birol et al. 2008; Broch and Vedel 2011; Latinopoulos 2014; Alcon et al. 2014; Cleland et al. 2015; Lienhoop and Brouwer 2015).

### 3.1.3. Choice experiments and water policy

Choice experiments were introduced by Louviere and Woodworth (1983) and have grown in popularity as a means for identifying preferences for environmental features and informing the design of environmental policies (Bennett and Blamey 2001; Birol and Koundouri 2008; Aizaki 2012). The vast majority of these studies have assessed willingness to pay for environmental conservation programs, and preferences for environmental outcomes associated with such payments (Brouwer 2008; Cooper et al. 2011; Duke et al. 2012; Jianjun et al. 2013). In dealing with water policy, choice experiments have mainly assessed willingness to pay for improvements in drinking water quality (Haider and Rasid 2002; Willis et al. 2005; Hanley et al. 2006; Thacher et al. 2011; Latinopoulos 2014; Brouwer et al. 2015). Only recently have choice experiments been used to investigate preferences about water policy design (Koundouri 2009). Some of these recent studies have focused on farmers' willingness to accept payments for setting aside agricultural land to provide buffer zones to improve water quality (Broch et al. 2012; Beharry-Borg et al. 2012; Lienhoop and Brouwer 2015), or willingness to enrol in such payment programs (Broch and Vedel 2011). One study focusing on farmer preferences for policy design for alternative water supply options (Katayama et al. 2009) noted that crop type was an important factor in farmers' preferences for irrigation sources. Other research has examined farmers' willingness to pay for water under different water allocation programs (Birol et al. 2008; Speelman et al. 2010; Chellattan Veettil et al. 2011; Alcon et al. 2014).

## 3.2. Methodology

### 3.2.1. Survey design and data analysis

The choice experiment was administered as a component of a custom programmed web-based survey. The questionnaire consisted of 9 short sections with 37 questions in total. The full questionnaire was designed to be completed in 15 minutes in recognition of the challenges experienced in surveying farmers (Pennings et al. 2002). In parts 1-5, information was gathered on farm characteristics, water use, and opinions on water use in the region. Part 6 gathered input on changing water policy and part 7 solicited opinions on changing climate (a detailed description of questionnaire responses for parts 1-7 can be found in Conrad (2013)). The choice experiment was presented in part 8, and part 9 ended the questionnaire with questions on the socio-economic characteristics of the respondent farmers. The questionnaire included "warming up" questions to ensure that farmers were sufficiently familiar with drought response plans and their elements (Krupnick and Adamowicz 2006).

Invitations to participate in the survey were mailed to farm contacts in the Okanagan watershed. For farms in the South East Kelowna Irrigation District (within the Okanagan watershed) the list of contacts was obtained from the records of the Irrigation District's water managers. For farms in the Okanagan watershed outside of the South East Kelowna Irrigation District, we developed our own contact list. We began by identifying lands zoned for agriculture, using spatial mapping in ArcGis Desktop 10.1. We overlaid BC Agricultural Land Reserve map layers on BC address cadastral layers to generate an address point file of possible farms in the province. Resulting point locations were visually verified using Google maps, and farms located outside the Okanagan watershed were eliminated, resulting in 8,403 possible farm locations. Inactive farms and non-irrigated properties were eliminated by comparing farm point locations to parcel data contained in the Okanagan Water Demand Model developed for the Okanagan Basin Water Board (Fretwell 2009). Contact names for the remaining farms were generated using a reverse lookup on 411.ca, a local telephone and address directory provider, and farm locations without contact data were eliminated.

The resulting address list, including contacts managed by the South East Kelowna Irrigation District, consisted of 1,512 addresses. These farms were contacted between March 2013 and May 2013. A modified tailored design method was followed, which included a lottery prize draw incentive for participating (Dillman 2007). The South East Kelowna Irrigation District mailed an initial contact letter to its farm customers with information about how to complete the online survey. The Irrigation District subsequently mailed a follow up reminder postcard and letter at week 3 and week 7, respectively. Farmers outside the South East Kelowna Irrigation District service area were contacted by the research team at the same intervals, but by postcard initially, with two reminders by postcard, based on our experience that post cards were effective in soliciting responses in a related residential study (Conrad 2012).

### 3.2.2. Design of the choice experiment

Policy options in the choice experiment were selected to represent a realistic application of a drought response plan as it might apply to the Okanagan region. Each scenario presented to respondents included a drought response plan incorporating several policy instruments, requiring respondents to simultaneously evaluate the different instruments and address associated trade-offs in a comprehensive fashion. We gave special attention to framing the choice experiment to present a realistic scenario with a set of attributes of importance to farmers.

The choice experiment approach is grounded in Lancaster's attribute theory of value and consumer choice (Lancaster 1966), and has an econometric foundation in random utility theory (McFadden 1974). Lancaster holds that consumers derive satisfaction not from the good itself but from the attributes contained in the good. Thus, for a drought response plan it is assumed that farmers derive satisfaction from the specific plan elements. The total utility they obtain from the plan is the sum of the utility obtained from each of the plan's elements. Random utility theory posits that choices can be modeled as a function of the attributes of the alternatives given (McFadden 1974; Train 2009). It is assumed that an individual selects the alternative ($i$) that has the greatest overall utility and that each attribute contributes to a part of the compound utility of the alternative. This type of selection of compound part-worth utilities ($a_i = a_i^1,\ldots, a_i^n$) indicates that the overall utility ($U_i$) of the alternative chosen is greater than the utility of the other alternatives. The higher the part-worth the higher the impact the attribute has on overall utility. The total utility of the alternative ($U_i$) can be represented with a deterministic component ($V_{(ai)}$) and stochastic (error) component ($\mathcal{E}_i$):

$$U_i = V_{(a_i)} + \mathcal{E}_i \qquad (11)$$

An alternative ($i$) is chosen over alternative ($j$) if and only if $U_i > U_j$ for all of $j$ and $i$. The probability of choosing $i$ over $j$ can be calculated as:

$$Prob(i|C) = Prob\{V_i + \mathcal{E}_i > V_j + \mathcal{E}_j \,; \forall j \in C\} \tag{12}$$

where $C$ refers to the set of all possible alternatives.

An advisory group, interviews, and focus group sessions guided us in designing the choice experiment. The advisory group included individuals from regional water providers and irrigation districts, provincial and local governments, agriculture associations, and the local academic community. The group offered advice and reviewed all stages of the study, providing suggestions on the drought response plan elements to be included and opinions about water management in the Okanagan agricultural community. Draft surveys were pre-tested in focus groups and individual interviews with farmers to ensure lucidity and clarity of the questionnaire and choice experiment. Based on feedback from the advisory group, focus groups and interviews, we decided to include wording in the introduction of the choice experiment to highlight the relevance for upcoming policy choices: "The BC government proposes to give regional water users more flexibility to develop their own drought response plans for times when their water requirements can no longer be met." We also framed the choice experiment as an engagement among farmers, to avoid the impression that we were researching options for reallocating water away from the agricultural community: "Imagine that you are working with a group of other farmers in your region to develop such a drought response plan."

### ***Drought Response plan elements and levels***

Table 3.1 describes the policy instruments that we included in our choice experiment, along with the possible levels of each instrument. Below, we explain the rationale for using these particular instruments and settings.

**Table 3.1. Drought response plan elements and levels**

| Elements (attributes) | Description | Levels[a] |
|---|---|---|
| **Across the board water use reduction (during peak of summer) ...** | Across the board reductions in all allocations as a % of farm water allocations. | 0%<br>15%<br>30% |
| **Water allocated according to (regional water needs) ...** | Strategy for allocating agricultural water during water shortages including proportional distributions to all farmers based on available water supplies, allocating water based on crop values, and allocating water based on how sensitive crops are to water loss | proportion distributions<br>crop value<br>sensitivity to water loss |
| **Opportunities for trading water (temporarily) ...** | System for allowable temporary water trades between license holders | none<br>between farmers<br>between all water users |
| **Impact on watershed's stream health** | Impact on overall stream health and aquatic environments | low<br>moderate<br>High |
| Context variable | **Description** | **Levels*** |
| **Likelihood of water shortage occurring** | Context variable expressing the relative likelihood of a water shortage occurring | 1 in 15 years<br>1 in 10 years<br>1 in 5 years |

[a]all elements are effects coded

We included across-the-board mandatory reduction in water use because this is one of the most common elements of a drought response plan and it has been used in the Okanagan in the past. The possible levels of reduction presented were based on historical reductions in the Okanagan following droughts, and also on assertions in the literature (supported by our interviews) that farmers have the capacity to absorb moderate reductions in water allocation in the short term. Levels for mandated reduction were therefore set at moderate levels of 0%, 15%, and 30%. A 0% level was included to represent a drought response that relied upon other elements within the plan to manage the water shortage.

Reallocation of water among users is another common strategy for dealing with water shortages. Three means for prioritizing water allocation during droughts were presented in the choice experiment. The first option, based on sensitivity of the crops to water loss, was included to recognize the irreversible effect of water loss for some types of crops. The second option, based on crop value, was included to recognize and measure economic priorities. The third option presented proportional distributions to measure preferences for shared distributions to farmers in the region.

The option of temporarily trading water during water shortages was included to investigate the acceptability of water trading for these farmers. The levels for water trading were set at “none”, “between farmers”, or “between all users”. Water trading was offered as an opportunity rather than a requirement, to make it clear that farmers could elect to trade water during droughts as best suited their operations.

Climate change is likely to influence the frequency and intensity of droughts and is likely to make drought response plans more attractive in the future. Therefore, we included a context statement presenting the likelihood of droughts occurring, set at 1 in 15 years, 1 in 10 years, or 1 in 5 years.

Our experiment did not include a monetary cost or payment mechanism to estimate monetary values associated with individual elements of the plan (as seen in many choice experiments). Initial testing of the choice experiment did include such a payment for reducing the amount of irrigated land. However, farmers participating in early focus groups expressed difficulties assessing how payments would apply to their farm, and said that payments did not factor into their selection of a preferred drought response plan. So instead of including a monetary cost for each scenario, we elected to include an environmental measure in the form a qualitative assessment of the impact (low, moderate, or high) of the drought response plan on stream health and aquatic environments. Improving stream health is also one of the goals of the 2014 British Columbia *Water Sustainability Act*. In this context, and in terms of identifying preferences concerning the acceptance of production losses against protecting environmental health, the inclusion of an environmental impact in the form of stream health was designed to provide policy relevant information.

The choice experiment was structured based on a statistical design and presented the hypothetical drought response plans organized in choice sets. Each choice set presented two alternative plans consisting of four elements each (including the impact on stream health) and one overall context variable setting out the likelihood of a water shortage (Fig. 3.2). An “opt out” option was not included in this experiment, as farmers would not normally have the option of excluding themselves from any regional drought response plan. With two drought response plans in each choice set, made up of four elements and associated levels, there were 19,683 possible plan designs ($3^4$ X $3^4$ X $3^1$). We used the SAS 9.3 experimental design macro *MktEx* to reduce the number of difference combinations and to produce an orthogonal main effects design with minimal overlapping of attribute levels (Street et al. 2005; Kuhfeld 2010). Use of this macro reduced the number of possible combinations to 36 choice pair sets, blocked into six different versions of six choice sets, reported as being optimally balanced with 100% D-efficiency.

| *Likelihood of water shortage occurring* | **1 in 15 years** | |
|---|---|---|
| Elements of a drought response plan | **Plan A** | **Plan B** |
| Across the board **water use reduction** (during peak of summer) ... | 30% | 15% |
| **Water allocated** according to ... | sensitivity of crop to water loss | proportional distributions |
| Opportunity for **trading** water ... | between all users | none |
| **Impact** on watershed's stream health | low | moderate |
| Please choose one ➔ | | |

**Fig. 3.2. An example choice set**

Farmers participating in the study were shown a randomized blocked set of six choice pairs from the six blocked sets. For the next respondent, another block of six choice pairs was drawn, until the pool of blocked sets was exhausted; at which point another round of set selection would start. For each choice set, respondents chose the drought response plan they preferred and continued to the next set until they completed six choice sets.

Prior to completing the six choice tasks respondents were shown an overview of how the elements of a drought response plan work together to reduce water use (Fig. 3.3), and an example choice set with instructions on how to interpret the presented plan elements.

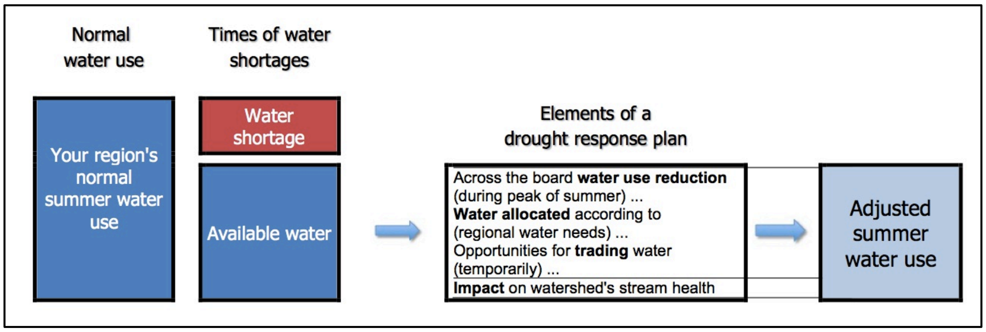


**Fig. 3.3. Illustration of how a drought response plan reduces water use**

### 3.2.3. Data analysis and multinomial logit model development

One-way ANOVA, Kruskal Wallis H, and Pearson Chi-Square tests were performed in SPSS 19 on attitudinal data against primary land use (the self-reported use of the "majority" of the land on the farm estimated from respondent's description of the approximate acreage of each crop type cultivated on their farm (Conrad 2013)): *Forage, Orchards, Vineyards, Ranch,* and *Mixed Use.* Statistically significant differences at the 95% confidence level are reported.

To model farmers' choices among the drought response plan alternatives and to investigate tradeoffs among plan elements, two multinomial logit models were estimated in Latent Gold 5.0. A single class multinomial logit model focuses on main effects. A second model, an extension of the single class model, includes a stepwise 'known class' segmentation by primary land use. Following Hensher et al. (2005) we reduced the number of degrees of freedom in Model 2 to present a consolidated model that is more statistically parsimonious. *P* values are two-tailed for all tests and z-values are reported at 1%, 5%, and 10% significance.

## 3.3. Results

The results are organized as follows: first, farm characteristics and respondent demographics are described; second, the single class multinomial logit model is presented, showing overall farmer attitudes and preferences toward drought response policy options; third, the ‘known class’ multinomial logit model profiling different preferences segmented by primary land use is presented and discussed.

A total of 265 respondents completed at least part of the web-based questionnaire. Of this total, 194 completed the full choice experiment, representing a 23% response rate after accounting for returned or undelivered invitations and elimination of incomplete responses. We report only the responses of those who completed the full choice experiment.

The Okanagan Basin contains various types of farms, including family farms, hobby farms, and commercial operations. The farmers who completed the choice experiment (Fig. 3.4) represented 8,920 acres (3,610 hectares) of land ranging from 1 acre (0.405 hectares) to 2,000 acres (809.4 hectares), with a median farm size of 7.0 acres (2.83 hectares). Orchard (apple and cherry) farms represented the largest acreage of crops cultivated for 25.3% of the respondents, followed by forage crops (17.0%), vineyards (14.4%), and ranching (12.9%). Mixed land uses represented 20.1% of the farms surveyed.

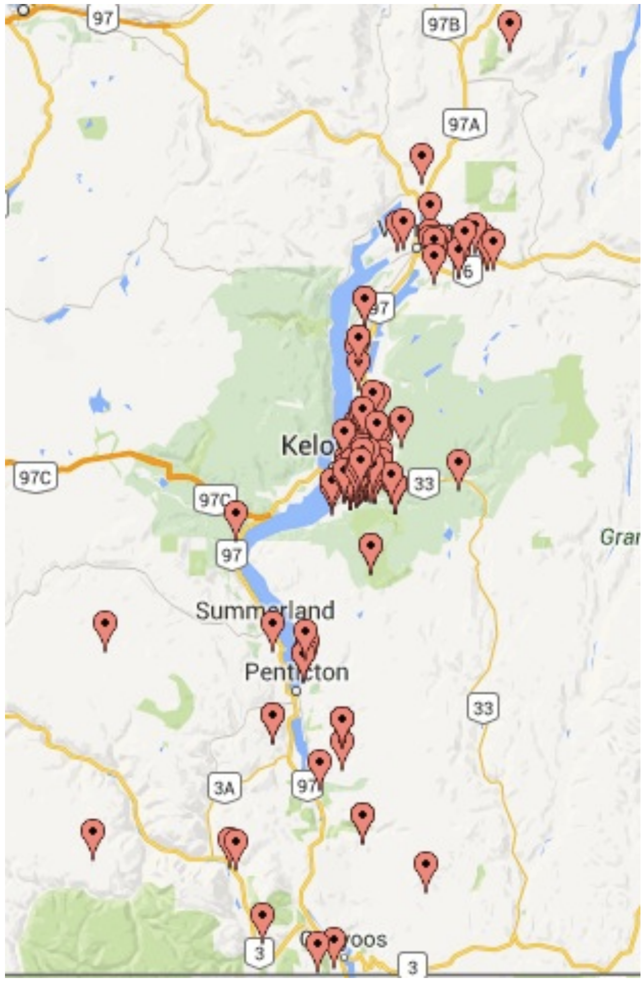

**Fig. 3.4.** **Farmer survey responses across the Okanagan Basin**
Source: Google maps and BatchGeo mapped postal code data, 2013

Respondents in our sample were primarily male (71.3%) and 45 to 65 years old (61.2%). They had been farming in the Okanagan region for a mean of 22.7 years and most were the owner or lessee of their farm (90.7%). The majority of respondents (61.3%) planned to continue farming in the Okanagan region for at least 5 years, and 36.6% planned to continue farming for more than 11 years.

### 3.3.1. Experiences with drought and perceptions of climate change

Farmers were asked to rank on a scale of (1 = never) to (5 = very often) how often they experienced any water shortages on their farm in the last 10 years and to rank the issues they perceived as causing the water shortages. Despite the occurrence of two major droughts in the Okanagan in the 10 years preceding our survey (Harma et al. 2012; Okanagan Basin Water Board), 71.6% of farmers indicated that water shortages had *never* affected their farm in the past 10 years. Of the remaining 28.4% of the farmers who indicated that they had experienced a water shortage, irrigation restrictions were noted as the cause for water shortages for 71.2% of these farms, followed by shortages of surface water supplies (46.2%), high costs of obtaining water (34.6%), and poor water quality (32.7%). Shortage of groundwater supply was viewed as the cause of water shortages for 32.7% of the respondents who indicated that they had experienced water shortages. These findings compare to Urquijo et al. (2015) in which a greater percentage of farmers in Spain who irrigated from surface water sources had a memory of experiencing the effects of drought as compared to farmers who irrigated from groundwater sources.

Over half of the farmers (55.7%) expressed the opinion that the first indications of climate change were already happening in the Okanagan region. Another 12.4% of farmers expected to see indications of climate change in the future, whereas 22.7% of farmers were undecided and 2.6% did not believe in climate change. When asked separately about specific climate related changes they noticed, farmers identified decreases in the severity of winters (53.6%), increases in the frequency of water shortages (19.6%), increases in the length of the growing season (20.1%), increases in extreme weather events (42.8%), increases in the number of pests (38.1%), and increases in the occurrence of early blooming (21.6%). A Kruskal Wallis H test did not reveal a statistically significant difference between farms categorized by land use or frequency of water shortages, however a chi-squared test of independence did reveal a relationship between land use and opinion on climate change. The relationship between these variables was significant, $X^2$ *(16, N = 176) = 27.8, P = 0.033*. Farmers who primarily farmed orchard crops were more likely to be undecided in their opinions about climate change than farmers of other crops, whereas farmers with vineyards were more likely to agree that climate change will happen but its indications are not yet apparent. The farmers who indicated that they did not believe in climate change were more likely to farm land for ranching or forage crops.

### 3.3.2. Farmers preferences toward drought response policy options

The multinomial logit model of the responses to the six choice tasks is shown in Table 3.2. Model selection was based on maximizing overall fit for main effects with an estimated McFadden pseudo-Rho$^2$ of 0.1548. The alternative specific constant (representing the role of all unobserved sources of utility) is a dummy coded variable of value 0 for Plan A and 1 for Plan B. The parameter estimates for this dummy variable revealed an unexpected preference for the first alternative of the unlabeled choice set. In other words, respondents showed a slight tendency to prefer the first of any two drought response plans presented in a choice set. A similar unlabeled choice preference is described in Cleland et al. (2015) and like these authors we suggest that the preference for the left alternative may relate to the visual processing for our given layout (Ossandón et al. 2014). We observed no effect on other parameter estimates when we included the alternative specific constant and we consider this finding to have little influence on the interpretation of results for the other attributes.

**Table 3.2. Results of the multinomial logit model[a] testing effects of drought response plan elements**

| Attribute and Attribute Level | estimate | s.e. | z-value[b] | p-value |
|---|---|---|---|---|
| Alternative Specific Constant | | | | |
| Drought response plan A | 0.0926 | 0.0321 | 2.8852*** | 0.0039 |
| Drought response plan B | -0.0926 | 0.0321 | -2.8852*** | |
| Across the board water use reduction | | | | |
| None (0%) | -0.2511 | 0.0641 | -3.9201*** | 0.0000 |
| Yes - 15% reduction | 0.3285 | 0.0639 | 5.1394*** | |
| Yes - 30% reduction | -0.0774 | 0.0637 | -1.6702* | |
| Water allocated according to… | | | | |
| Proportional distributions | 0.2036 | 0.0624 | 3.2620*** | 0.0000 |
| Crop Value | -0.4227 | 0.0655 | -6.4553*** | |
| Sensitivity of crop to water loss | 0.2190 | 0.0643 | 3.4044*** | |
| Opportunities for trading water | | | | |
| None | -0.1676 | 0.0639 | -2.6252*** | 0.017 |
| Yes - Between farmers | 0.1478 | 0.0652 | 2.2690** | |
| Yes - Between all users | 0.0198 | 0.0649 | 0.3055 | |
| Impact on watershed's stream health | | | | |
| Low | 0.4611 | 0.0654 | 7.0492*** | 0.0000 |
| Moderate | 0.1365 | 0.0625 | 2.1824** | |
| High | -0.5975 | 0.0666 | -8.9761*** | |

[a]$Rho^2$=0.1548
[b]*** Indicates significance at 1 % level, ** at 5 %, and * at 10 %

Also contrary to our expectations, the context variable *likelihood of water shortages* did not play a significant role either as a main effect or an interaction in farmer choices, so we excluded it from the model. The explanation for this result may lie in the experiences of these farmers during recent droughts. Given that only 28.4% indicated that water shortages had affected their farm in the last 10 years, and just 19.6% were of the opinion that climate change is increasing the frequency of water shortages, the impact of water shortages on these farmers may be muted despite the reoccurrence of drought. It is possible that local water storage combined with residential watering restrictions may have moderated the effect of drought on the Okanagan agricultural community in recent years.

The multinomial logit model does reveal that all other drought response plan elements shown in Table 3.1 had significant impact on farmer choices. Parameter estimates *for across the board water use reductions* show a general preference for a moderate level (15%) of mandated water use reductions, whereas 0% and 30% reductions negatively impacted the choice of drought response plans containing these levels. If the drought response plan included *opportunities for water trading*, farmers were significantly more likely to choose the plan. In plans with trading opportunities, the opportunity for trading between farmers was preferred over trading between all users. Farmers' concerns about the *Impact on watershed's stream health* were evident in the negative preference by farmers for increasing impacts presented in the drought response plan. That is, the higher the impact, the less likely farmers were to choose a drought response plan alternative with this element. Farmers also expressed significant preference for allocating water based on the sensitivity of crops to water loss and for allocating based on proportional distributions. Parameter estimates for both elements are positive and nearly equal. In contrast, farmers were less likely to select drought response plans that allocate water based on crop values.

Table 3.3 presents the results of a 'known class' model with set membership based on the majority land use of the farms in the study: *Forage, Orchards, Vineyards, Ranch,* and *Mixed Use.* This model shows that while farmers in the Okanagan were homogenous with respect to land use in their preferences for water allocation policies and allowance for impacts on stream health, differences are present between land uses in preferences for opportunities for trading and mandated water reductions. Farmers whose primary land use was vineyards may not consider mandated reductions in choosing a drought response plan. While all other types of farmers showed a dislike for no restrictions, farmers of vineyards were indifferent. Vineyard farmers were also more likely to agree with drought response plans that offered trading opportunities between all users and less likely to agree with plans that restricted trading to between farmers, even in comparison with plans that offered no trading opportunities. Conversely, trading opportunities between all users negatively influenced the choices of farmers whose land consisted primarily of ranch use, whereas they most preferred trading opportunities between farmers. Ranch land farmers were also less likely to agree with drought response plans that included no mandated water use reductions, and more likely to support plans that offered increasing amounts of water use reductions. Farmers whose primary harvest was forage crops also expressed positive preference for drought response plans that included trading opportunities between farmers, but may not agree with plans that offered no trading opportunities or trading opportunities between all users.

**Table 3.3. Results of the 'known class' multinomial logit model testing effects of drought response plan elements[a]**

| | Forage | | Orchards | | Vineyards | | Ranches | | Mixed | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Attribute and Attribute Level** | **Estimate** | **(s.e.)[b]** | **Estimate** | **(s.e.)[b]** | **Estimate** | **(s.e.)[b]** | **Estimate** | **(s.e.)[b]** | **Estimate** | **(s.e.)[b]** |
| *Opportunities for trading water* | | | | | | | | | | |
| None | -0.3893 | 0.1621** | -0.2845 | 0.1438** | -0.3497 | 0.1727** | -0.2478 | 0.1919 | -0.0469 | 0.1339 |
| Yes - Between farmers | 0.4596 | 0.1696*** | 0.2614 | 0.1377* | -0.3769 | 0.2064* | 0.5005 | 0.1981** | -0.1815 | 0.1336 |
| Yes - Between all users | -0.0703 | 0.1721 | 0.0231 | 0.1265 | 0.6266 | 0.1862*** | -0.2527 | 0.2000 | 0.2284 | 0.1422 |
| *Across the board water use reduction* | | | | | | | | | | |
| None (0%) | -0.2735 | 0.0803*** | -0.2735 | 0.0803*** | 0.0286 | 0.1764 | -0.4522 | 0.2046** | -0.2735 | 0.0803*** |
| Yes- 15% reduction | 0.4253 | 0.0806*** | 0.4253 | 0.0806*** | 0.2137 | 0.1757 | 0.1015 | 0.1957 | 0.4253 | 0.0806*** |
| Yes - 30% reduction | -0.1518 | 0.0800* | -0.1518 | 0.0800* | -0.2423 | 0.1766 | 0.3508 | 0.1988* | -0.1518 | 0.0800* |
| *Water allocated according to…* | | | | | | | | | | |
| Proportional distributions | 0.2283 | 0.0668*** | 0.2283 | 0.0668*** | 0.2283 | 0.0668*** | 0.2283 | 0.0668*** | 0.2283 | 0.0668*** |
| Crop Value | -0.4474 | 0.0710*** | -0.4474 | 0.0710*** | -0.4474 | 0.0710*** | -0.4474 | 0.0710*** | -0.4474 | 0.0710*** |
| Sensitivity of crop to water loss | 0.2191 | 0.0680*** | 0.2191 | 0.0680*** | 0.2191 | 0.0680*** | 0.2191 | 0.0680*** | 0.2191 | 0.0680*** |
| *Impact on watershed's stream health* | | | | | | | | | | |
| Low | 0.4358 | 0.0689*** | 0.4358 | 0.0689*** | 0.4358 | 0.0689*** | 0.4358 | 0.0689*** | 0.4358 | 0.0689*** |
| Moderate | 0.1493 | 0.0668** | 0.1493 | 0.0668** | 0.1493 | 0.0668** | 0.1493 | 0.0668** | 0.1493 | 0.0668** |
| High | -0.6030 | 0.0708*** | -0.6030 | 0.0708*** | -0.6030 | 0.0708*** | -0.6030 | 0.0708*** | -0.6030 | 0.0708*** |

[a] $Rho^2$=0.1659; The consolidated model, indicated by ☐, is more statistically parsimonious; Known class segmentation presents smaller sample sizes for model estimations resulting in increased standard error

[b] Standard Error *** Indicates significance at 1 % level, ** at 5 %, and * at 10 %

## 3.4. Discussion

In this choice experiment, drought response plans that imposed reductions in water supply or that offered the option of water trading were more acceptable to farmers in the Okanagan than we had anticipated based on the literature and our focus groups. Concerning water supply, water managers and policy makers often assume that farmers will oppose changes in water allocation that involve any reductions in the amount of water that farmers will receive. For instance, one influential opinion expressed in the literature and by our pre-survey participants is that farmers tend to view water use mainly in terms of crop productivity. From this perspective, any reduction in water availability may be perceived as a risk to farm productivity. A demand to reduce water use may also go against farmers' conviction that they are already using water efficiently; using just the right amount of water in the right place at the right time (Knox et al. 2012).

The results of our choice experiment, however, indicate that farmers in the Okanagan are willing to consider drought response plans that include mandated water reductions for the agricultural sector. The single class model shown in Table 3.2 reveals a preference for drought policies with moderate water use reductions. The known class model shown in Table 3.3 refines this acceptance, showing that farmers whose primary land use was vineyards differed from other farming groups in that vineyard farmers may not consider water use reductions in choosing a drought response plan. It may be that vineyard farmers believe that they are already using water efficiently — vineyards in the Okanagan generally require less water than orchards, forage, and many other types of crops — and believe that they do not have room to accept reductions in their allocation of water. We make this inference cautiously, however, as our study did not attempt to quantify any excess water individual respondents might have in their water allotments.

Another assumption expressed in our pre-survey focus groups was that farmers in the Okanagan would oppose policy options involving water trading. Our findings provide evidence to the contrary. The choice models show that farmers expressed a preference for water trading opportunities when considering drought response policies. Interestingly, farmers participating in pre-survey interviews also discussed the existence of an unregulated culture of trading between farmers during water shortages, especially between farmers drawing irrigation water from the same stream. These findings contrast with statements from farmers and other stakeholders recorded during province-wide public consultations as part of the British Columbia *Water Act* modernization process, expressing strong opposition to water trading (British Columbia Ministry of Environment 2010c). We offer that choice experiments provide an alternative means for soliciting independent and broad input on such controversial issues and offer data to supplement findings gathered from other public participatory processes.

Apart from these perspectives on mandated water use reductions and water trading opportunities, our choice experiment reveals several other interesting aspects of farmers' positions on water allocations during drought in the Okanagan. Participating farmers preferred proportional allocations, or allocations based on crop resource requirements, to allocations based on crop value. This preference was evident across all land uses and suggests that farmers take into account factors other than just economic return in their decisions about managing agricultural lands.

Furthermore, the choices of farmers in our experiment demonstrate that the effect of a drought response plan on watershed health was an important consideration in their assessment of alternative plans. Many farmers in the Okanagan receive irrigation water from cooperative irrigation districts or from local streams, and directly participate in the management of these water supplies. Pre-survey interviews suggested that farmers were aware of the connection between land use and watershed management. Many farms in this region are also family owned or independent of major agricultural producers. Our findings align with other research that has found that many residents in the Okanagan region strongly favour environmental protection and conservation (Conrad 2012; Janmaat 2013). Overall, we found that the preferences of Okanagan farmers about drought response policy instruments are more complex than is sometimes assumed, and that in addition to the economic factors often emphasized in discussions about farmers' water use decisions, they appear to give weight to ecological factors and social relationships with other farmers and other water users.

## 3.5. Policy implications for Okanagan drought response planning

The new BC *Water Sustainability Act* includes provisions that allow the possibility of more regional flexibility and control of water planning and allocation, including local policies for the management of water shortages. Three main implications can be drawn from the findings of this study to inform and guide regional drought response policies in the Okanagan.

First, the finding of negative preferences, across all farm types, for water allocations based on crop value indicates that farmers may prefer that allocations be based on principles other than simply economic productivity. Proportional allocation doctrines and allowances for prioritizing water based on crop requirements should play an important role in drought response policies in the Okanagan. When combined with elements such as water trading and moderate reductions in water use such allocation methods may contribute to drought response plans that are more acceptable across all farm types.

Second, our study suggests that a moderate reduction of water supply (e.g. 15%) during a water shortage would be acceptable to farmers in the Okanagan, and could serve as a key element of a drought response plan for the agricultural sector in this region. When water users support a mandated reduction it can foster compliance and reduce the costs of enforcement. More extensive levels of water use (e.g. 30%) were less acceptable to farmers in our study, suggesting that compliance and enforcement would be more challenging if water managers impose larger reductions.

Third, our finding that farmers were amenable to water trading opportunities could inform a strategy for managing agricultural production during droughts as well as encouraging drought preparedness. Dridi and Khanna (2005) found that water trading led to additional adoption of water efficient technology, and Kiem (2013) reports that water trading helped irrigators make more flexible production decisions in response to external factors including changes in water allocations. Temporary trading opportunities in a drought response plan would offer farmers more flexibility in making production decisions during times of limited water supply, as well as providing them with a legal framework for collectively managing shared watersheds. At the time of our research, BC’s water legislation did not allow water trading, yet pre-survey interviews revealed an active underground trading network, through which farmers worked together to manage short term water shortages. The flexibility and opportunity for adaptation offered by water trading may become increasingly important as farmers adjust to the effects of climate change in the Okanagan.

In summary, Okanagan water managers may wish to consider setting policy for drought response plans that include moderate water use reductions for agricultural water users, mechanisms for prioritizing water allocations based on crop sensitivity to water losses, and mechanisms for water trading.

## 3.6. Conclusion

The choice experiment discussed in this paper investigated farmers’ preferences concerning policy instruments that could be included in a drought response plan for the Okanagan region. The results challenge some commonly held assumptions about farmers being opposed to water trading and reductions in water allocation for agricultural uses. The fact that many farmers in our study were willing to choose water reductions under the conditions expressed suggests that they view their water use more broadly than a simple resource transaction. Further research in this area could explore the decision and motivational factors that underpin this finding. Second, the finding of positive stated preferences for water trading under drought conditions adds to the broader research on agricultural water markets. Whether these preferences for water trading extend to non-drought conditions is an area requiring additional study. Finally, the finding that farmers of different crop types differ in their preferences about drought responses suggests the possibility of tailoring drought response measures to different farm types.

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# Chapter 4.

# Coupling stated preferences with a hydrological water resource model to inform water policies for residential areas in the Okanagan Basin, Canada

*This chapter has been submitted to the Journal of Hydrology as: Conrad, S. and Yates, D., "*Coupling stated preferences with a hydrological water resource model to inform water policies for residential areas in the Okanagan Basin, Canada.*" I developed the coupled model described in the research and conducted the analyses. I also prepared the tables and figures for this paper and authored the majority of the text. Technical assistant was provided in preparing the model described in this research by Ettore Pureza Leonel Bigi de Aquino and Summit Environmental.*

## Abstract

To improve the behavioural realism of a water resource model, this study coupled hydrologic modelling with stated preference research, thereby incorporating an empirical estimate of behavioural parameters to represent residents' landscape decisions in an urban environment. The stated preference data came from a discrete choice experiment in which residents were asked to choose among several possible lawn plots — varying in size, turf variety, and aesthetic qualities. The discrete choice experiment also included subsidies for lawn replacement, and information about estimated water use and watering costs for each lawn choice. We prepared a multinomial logit model from the stated preference data, and then coupled it with a water resources model of the Okanagan Basin using the Water Evaluation and Planning System. We then conducted a scenario analysis using the coupled socio-hydrological model to simulate the extent to which residents would adopt alternative lawns under varying incentives and subsequently computed corresponding changes in water demand. The results indicate that proposing alternative lawn configurations to residents and providing site-specific information about the potential for reduced watering costs, along with a small subsidy, could lead to considerable reduction of outdoor water use through voluntary adoption. Under a scenario in which the attributes of the suggested lawn configuration matched those most preferred by residents in the choice experiment, the suggested configuration was widely adopted in the Okanagan, but a scenario with a more extreme water conserving lawn configuration reduced overall outdoor water use by a greater amount even though the configuration was adopted by a smaller percentage of residents. This study illustrates the relationship between lawn preferences and water use and reinforces calls to integrate hydrological and social modelling in order to capture the complex interactions between human behaviour and water use.

**Keywords**: coupled socio-hydrological model, socio-ecological systems, water resource models, consumer stated preferences, water supply and demand, water policymaking

## 4.1. Introduction

Water resource planning increasingly recognizes that human and ecological systems are complex adaptive systems, characterized by cross-scale interactions and high uncertainty (Levin 1998; Folke et al. 2005; Mitchell et al. 2012). Accordingly, scholars have called for new research on the development of coupled socio-ecological models, which represent human interactions with water resource systems. For example, Sivapalan et al. (2012) argue for a new science of socio-hydrology to explore how coupled human-water systems co-evolve. Socio-hydrology can generate quantitative descriptions of system behaviour for modelling and forecasting possible future states. Carey et al. (2014) propose a framework for hydro-social modelling to capture the human variables critical to hydrological modelling. Troy et al. (2015) explore the development of socio-hydrologic modelling, noting that it is still unclear whether existing examples of coupled human-water models reflect an over-emphasis on calibrated data or an accurate representation of known human-water relationships.

The study of coupled socio-hydrological modelling is still in its infancy and the parameterization of human behaviour in water resource models remains relatively rare. This lack of attention prompts for investigation into new approaches for understanding coupled human and water resource systems. These approaches should support better integration of socio-economic research with hydrological models in order to simulate the interactions of human systems with hydrological systems, address water needs for society and ecosystems, and represent the dynamic nature of water demand (Carey et al. 2014). In our research, we developed a socially coupled water resource model for residential landscapes in the Okanagan Basin of British Columbia, Canada. The model demonstrates the effects that residents' preferences concerning their lawns under various scenarios will have on water use.

The coupled socio-hydrological model (the "Okanagan coupled model") is designed for use as a decision support tool to inform policies for managing water demand in the Okanagan Basin. The model uses the Water Evaluation and Planning System (WEAP – a water management and allocation system developed by Raskin et al. (1992) and the Stockholm Environment Institute) and a discrete choice model derived from a discrete choice experiment to examine the influence of residential landscape choices on regional water supplies. We applied the Okanagan coupled model in a subwatershed within the Okanagan Basin for alternative lawn scenarios to investigate changes in water demand. In this paper, we describe the process we developed for coupling the discrete choice model with WEAP and the resulting information provided to decision makers. To our knowledge this paper presents the first application of a discrete choice model being fully coupled with a water resource model, moving beyond the simple linking of outputs from separated models or frameworks. The results illustrate how the Okanagan coupled model provides water demand simulations based on hydrological and behavioural modelling, including empirical evidence of the preferences of water users, allowing for more informed policymaking.

This paper is organized as follows: An overview of the study area is given in the remainder of section 4.1. Section 4.2 discusses the parameterization of the WEAP software with water supply and demand data in the Okanagan Basin. We include a description of the theory and calculations underlying the preference data and how the data were used to estimate the behavioural parameters in the Okanagan coupled model. In section 4.3 we demonstrate how the Okanagan coupled model can be used for behaviourally realistic scenario analysis. Section 4.4 provides a discussion of the results and assesses the usefulness of the approach.

### 4.1.1. Study area

The Okanagan Basin covers 8,046 km$^2$ in British Columbia, Canada (Fig. 4.1) and is unique in that it has the highest ratio of population to annual surface water yields of any basin in Canada (Statistics Canada 2010). The Okanagan Basin has a small water catchment, and is undergoing rapid population growth in a changing climate (Merritt et al. 2003; Cohen et al. 2004; Taylor and Barton 2004). Surface water is a major supply source, meeting 67% of the region’s water demand (Summit Environmental 2010a). Historically, water managers have mainly used surface water storage to meet growing water demand (McNeill 2004); however, future scenario modelling suggests that existing surface water storage systems will be unable to meet municipal and instream flow needs by 2050 (Harma et al. 2012).

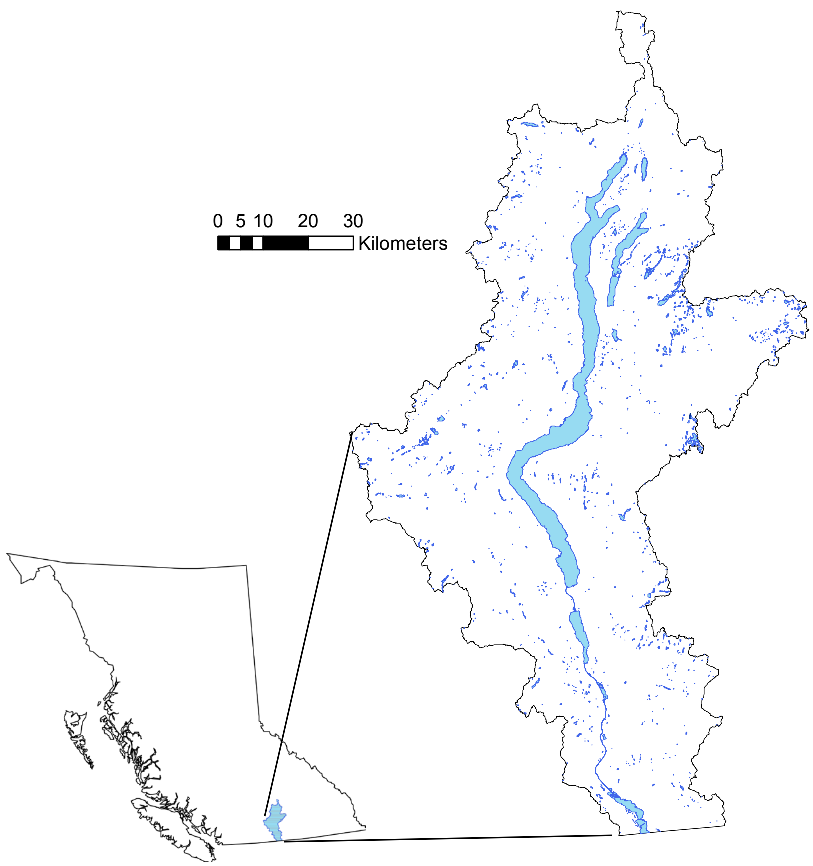



**Fig. 4.1. Map of the Okanagan Basin Watershed in British Columbia, Canada**
Source: ArcGIS 10.2

To study these issues, in 2007 the Okanagan Basin Water Board (a collaboration of local governments, water suppliers and First Nations) initiated the development of two regional planning models for water and land use in the region. The first, the Okanagan Water Demand Model, estimated water needs for residential, agricultural, and industrial and commercial uses, based on land survey data, GIS and cadastral mapping of crop types – including turfgrass, irrigation system types, soil properties, and climatic data (Summit Environmental 2010b). The second model, the Okanagan Water Accounting Model (OWAM), estimated natural streamflows and the effects of water storage and extractions on streamflows and lake levels in the Okanagan Basin (DHI Water and Environment 2010). Neither of these models included a coupled social component. These models did, however, provide the hydrologic basis for our study as well as a foundation for considering water management strategies and policies in the Okanagan Basin.

At the time of our research, the Okanagan Basin Water Board had initiated a new phase of work to increase the availability of data, refine modelling tools, and improve public consultation in policy development. This timing presented a window of opportunity to evaluate methods for increasing the predictive capacity of water resource models of the Okanagan Basin, by including a representation of water user behaviour. A key point of interest for water providers in the Okanagan Basin is the impact population growth will have on water supplies as rural landscapes transition to residential land uses.

The population of the Okanagan basin grew by 46% during the period 1990-2010, from 235,793 to 345,831 (Folke et al. 2005; Mitchell et al. 2012; BCStats). Accompanying this growth was the expansion of single family residential development, with large lawns that require more water to maintain compared to higher density developments (Maurer 2010). Irrigating these residential lawns accounts for 24% of all water use in the Okanagan Basin; the second largest use of water after agricultural irrigation (Summit Environmental 2010a). Therefore, predicting how residential consumers will respond to water demand management strategies and policies targeting residential landscapes is critical for wise decision making about water management in the Okanagan.

## 4.2. The Okanagan Coupled Model

In addition to the previously mentioned WEAP, there exist many possible basin wide water modelling systems, including RIBASIM (Hydraulics 2004), MIKE BASIN (DHI Water and Environment 2009), AQUATOOL (Andreu et al. 1996), and MODSIM (Labadie 1995). We selected WEAP as the modelling platform because of its broad use as a decision support tool and because the Okanagan Basin Water Board was planning to adopt WEAP as a water management tool. Also, WEAP is a platform that provides flexibility in structuring water demand data by various measures of social and economic activities (e.g. water use rates per household, water use rates, number of households with lawns) (Yates et al. 2005),

The WEAP platform is a water management and allocation tool that has a graphical user interface to guide model parameterization. WEAP uses a mass balance accounting framework to calculate a monthly water balance of flows, changes in reservoir and groundwater storages, and water supply allocations to water demands and outflows (Yates et al. 2005). WEAP uses a linear programming heuristics approach to consider demand priorities and supply preferences to simulate both natural processes and human influences. Key assumptions may be built into the accounting to represent policies, costs and other factors that affect demand, supply, and the overall hydrologic cycle. A scenario feature allows the user to explore the effect of changes in climate and water management strategies on water systems, making WEAP well suited for evaluating human influences on water systems and informing water policymaking (Yates et al. 2005).

As a decision support tool, WEAP has been used to explore human-water interactions in a number of case studies. Swiech et al. (2012), for example, analyzed the impacts of a reservoir for improved agricultural production in the Yarabamba region, Peru with a WEAP model application. In another WEAP modelling application for Benin, Höllermann et al. (2010) applied different scenarios of socio-economic development and climate change to review Benin's future water situation through 2025. Bhave et al. (2014) used WEAP to model the effect of stakeholder prioritized climate change adaptation options for the Kangsabati river catchment in India. Hellegers et al. (2013) used WEAP to model trade-offs between water supply and demand to examine deficits against climate change scenarios in Iran, Morocco and Saudi Arabia. Recently, Safavi et al. (2015) used expert knowledge to prepare underlying data in a river basin model using WEAP for the Zayandehrud River Basin.

WEAP has also been previously used to examine water supply and demand in the Okanagan basin. Harma et al. (2012) utilized WEAP to investigate future climate scenarios in unregulated and reservoir-supported streams that supply the District of Peachland, in the Okanagan. After the initiation of our research, WEAP was selected by the Okanagan Basin Water Board as a platform for investigating the effects of the prior appropriation principle used in the British Columbia water licensing system (Summit Environmental 2013). The resulting model examines connected water use between communities and is being used as a decision support tool for regional drought response plans and new water licensing decisions. This Okanagan Hydrologic Connectivity Model provided the hydrological structure (e.g., rivers, reservoirs, lakes) for preparing the Okanagan coupled model.

The conceptual framework for the Okanagan coupled model is shown in Fig. 4.2. The model consists of a discrete choice model and a hydrological representation of a water resource system. A monthly time step was used to prepare water supply and demand data for the known system (2010), to couple stated preference data, and to prepare future scenarios for the analysis period (2011-2015).

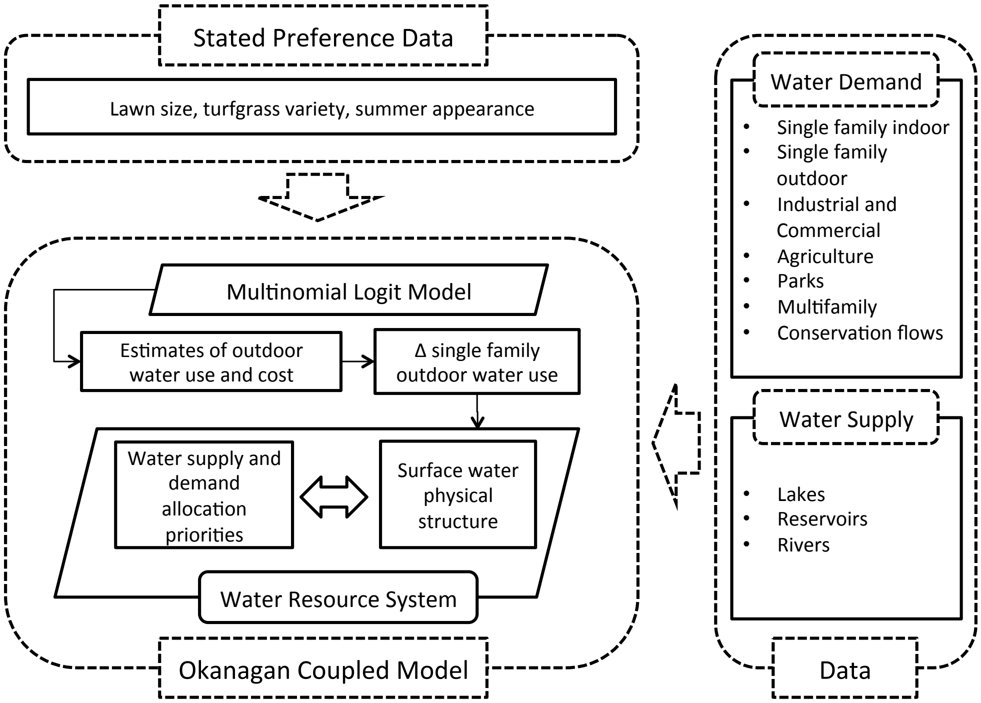



**Fig. 4.2. Coupled socio-hydrological study framework and conceptual model**

### 4.2.1. Stated preference data and the multinomial logit model

To prepare the behavioural component of the Okanagan coupled model we used stated preference data from a choice experiment to estimate the choices that would be made by residents with regard to landscaping features under various conditions. Stated preference data refer to observations that are derived from survey data in which respondents express what their choice would be in a hypothetical scenario, whereas revealed preference data come from observations of actual behaviour. We chose to use stated preference data rather than revealed preference data for two reasons. First, comprehensive data on lawn configurations and resultant water use are not readily available in the Okanagan region. Second, revealed preference data may be insufficient to represent the impact of policies that have not been previously attempted, or that drive water use behaviour beyond historic limits.

A detailed discussion of the discrete choice experiment and resulting stated preference data used to form the multinomial logit model (i.e. the discrete choice model) component of the Okanagan coupled model is provided in Chapter 2. The choice experiment presented six sets of three alternative lawns (Fig. 4.3) with varying attribute levels (Table 4.1); two of the lawns in each set were hypothetical and one was based on the respondent's description of his or her own lawn. For each choice set, the respondent was asked to choose their preferred lawn.


**Fig. 4.3. Example choice set**

**Table 4.1. Lawn attributes and levels**[a]

| Attribute | Levels | Description |
|---|---|---|
| *% of total landscape* | 25% Turf<br>50% Turf<br>75% Turf<br>100% Turf | Represents the proportion of turfgrass covering the landscapable area in a residential yard |
| *Variety of turf* | Traditional<br>Water Conserving<br>Artificial | Describes the majority type of turfgrass used in the lawn:<br>Traditional variety of turf (Kentucky Blue Grass, Ryegrass)<br>Water-conserving variety of turf (eco-Smart Blend, Sheep Fescue, Chewings Fescue)<br>Artificial or synthetic turfgrass |
| *Appearance during peak of summer* | Very Green<br>Mostly Green<br>More Green than Brown<br>More Brown than Green | Describes how green or brown a resident's lawn may appear during the peak of summer when watering requirements are highest |
| *One time Subsidy to reduce or replace* | $125<br>$250<br>$375<br>$500 | Presents a one-time payment to residents for selecting the lawn alternative |

[a] Data source: (Chapter 2)

The analysis of data derived from the discrete choice experiment is grounded in Lancaster's attribute theory of value and consumer choice (Lancaster 1966), and has an econometric basis in random utility theory (McFadden 1974). Following Lancaster, we assume that residents derive satisfaction from the features or attributes that constitute the lawn. The total utility, or value, they obtain from a specific lawn is the sum of the utility obtained from each of the lawn's attributes. According to random utility theory, choices can be modeled as a function of the attributes of the lawn alternatives given (McFadden 1974; Train 2003). It is assumed that an individual selects the lawn alternative $i$ that has the greatest overall utility and that each attribute contributes to a part of the compound utility of the alternative. This type of selection of compound part-worth utilities ($a_i = a_i^1, \ldots, a_i^n$) indicates that the overall utility $U_i$ of the lawn alternative chosen is greater than the utility of the other lawn alternatives. The total utility of the alternative $i$ can be represented with a deterministic component $V_{(a_i)}$ and stochastic (error) component $\mathcal{E}_i$:

$$U_i = V_{(a_i)} + \varepsilon_i \tag{13}$$

A lawn alternative $i$ is chosen over lawn alternative $j$ if an only if $U_i$ > $U_j$ for all of $i$ and $j$. The probability of choosing $i$ over $j$ can be calculated as:

$$Prob(i|C) = Prob\{V_i + \varepsilon_i > V_j + \varepsilon_j\ ; \forall j \in C\} \tag{14}$$

where $C$ refers to the set of all possible lawn alternatives.

A function derived from utility $U_i$ can be expressed to ascertain a relationship between observed attributes, unobserved attributes, and stated (or observed) choice outcome. The probability $P_i$ of an individual choosing lawn alternative $i$ out of the set of $q$ lawn alternatives is provided by:

$$P_i = \frac{\exp V_i}{\sum_{\mathrm{h}} \exp V_q}; \quad \text{(for all q in choice set C where i} \neq \text{q)} \tag{15}$$

Derivation of the above equation results in the multinomial logit model frequently used as the basis for analyzing choice experiments (Adamowicz et al. 1998; Louviere et al. 2000; Hensher et al. 2005).

In our choice experiment, individuals were also asked to describe their existing lawn conditions, or attributes, which were then included in the set of alternatives as an existing lawn, or status quo, alternative. These status quo attributes can be expressed as predictors to refine the multinomial logit model by providing characteristics of the choice set or respondent across the alternatives. Expressing $V_{(a_i)}$ above as the probability that an individual selects lawn alternative $i$ at replication $t$ given attribute values $z_{it}^{att}$ and predictor values $z_{it}^{pre}$ for all responses $y_{it}$ is given by:

$$P\left(v_{(a_i)} = j \middle| z_{it}^{att}, z_{it}^{pre}\right) \tag{16}$$

The above specification can be adapted to provide a new regression model where the systematic component in the utility of lawn alternative $j$ for case $i$ at replication $t$ is represented by:

$$P\left(y_{it} = j \middle| z_{it}^{att}, z_{it}^{pre}\right) = \frac{\exp\left(\eta_{j|z_{it}}\right)}{\sum_{j'=1}^{J} \exp\left(\eta_{j'|z_{it}}\right)} \tag{17}$$

where, following McFadden (1974), the term $\eta_{j|z_{it}}$ is a function of the status quo bias, or alternative specific constant, $\beta_j^{con}$, attribute effects $\beta_p^{att}$, and predictor effects $\beta_{jq}^{pre}$. The indices $p$ and $q$ refer to particular attributes and predictors. $P$ and $Q$ denote the total number of attributes and predictors respectively:

$$\eta_{j|z_{it}} = \beta_j^{con} + \sum_{p=1}^{P} \beta_p^{att} z_{itjp}^{att} + \sum_{q=1}^{Q} \beta_{jq}^{pre} z_{itq}^{pre} \tag{18}$$

where for effect coding, $\sum_{j=1}^{J} \beta_j^{con} = 0$, and $\sum_{j=1}^{J} \beta_{jq}^{pre} = 0$ for $1 \leq q \leq Q$.

Part worth utility coefficients for the multinomial logit model component of the Okanagan coupled model are presented in Table 4.2. The negative coefficient for the alternative specific constant specifies an overall preference for existing lawns, or the status quo, in residential landscapes. This preference is, however, refined by the utility individuals have for the attributes describing their existing lawn, represented by status quo predictors (Chapter 2). Table 4.3 provides a listing of the status quo predictor coefficients coded in the Okanagan coupled model. The resulting multinomial logit model structure, one of part worth utilities and predictor coefficients, provides the framework for estimating choices and including behavioural data in the Okanagan coupled model.

**Table 4.2. Part worth utility estimates for *lawn alternatives* used in Okanagan coupled model[a]**

| Attribute | Level | Coefficient | z-value[c] |
|---|---|---|---|
| *Alternative Specific Constant* | | 0.658 | 4.247*** |
| *% of total landscape* | 100% Turf | -1.356 | -11.988*** |
| | 75% Turf | -0.090 | -1.209 |
| | 50% Turf | 0.781 | 11.548*** |
| | 25% Turf | 0.665 | 8.464*** |
| *Variety of turf* | Artificial | -0.239 | -2.228** |
| | Traditional | -0.180 | -2.581*** |
| | Water Conserving | 0.419 | 6.162*** |
| *Appearance during peak of summer* | Very Green | -0.188 | -2.426** |
| | Mostly Green | 0.293 | 4.228*** |
| | More Green than Brown | 0.172 | 2.610*** |
| | More Brown than Green | -0.277 | -3.836*** |
| *Subsidy (Linear)* [b] | | -0.002 | -0.144 |
| *Subsidy (Quadratic)* [b] | | 0.064 | 1.650* |
| *Lawn Watering Cost (Linear)* [b] | | -0.0008 | -3.829*** |

[a] Data source: (Chapter 2)
[b] Per $CAD
[c] *** indicates significance at 1 % level, ** at 5 %, and * at 10 %

**Table 4.3. Current lawn (*status quo*) predictors used in Okanagan coupled model[a]**

| Attribute | Level | Coefficient | z-value[b] |
|---|---|---|---|
| *% of total landscape* | 100% Turf | -0.538 | -2.559*** |
| | 75% Turf | -0.419 | -5.134*** |
| | 50% Turf | 0.159 | 1.939** |
| | 25% Turf | 0.799 | 8.957*** |
| *Variety of turf* | Traditional | -0.217 | -2.738*** |
| | Water Conserving | 0.217 | 2.738*** |
| *Appearance during peak of summer* | Very Green | 0.152 | 1.103 |
| | Mostly Green | 0.021 | 0.328 |
| | More Green than Brown | -0.034 | -0.551 |
| | More Brown than Green | -0.139 | -1.640 |
| *Property Size* | Small urban lot | 0.026 | 0.195 |
| | Average urban lot | 0.035 | 0.345 |
| | Large urban lot | 0.093 | 0.919 |
| | Larger than average urban lot | -0.377 | -2.684*** |
| | Very large urban lot/rural property | 0.223 | 0.694 |

[a] Data source: (Chapter 2)
[b] *** indicates significance at 1 % level, ** at 5 %, and * at 10 %

### 4.2.2. Lawn watering cost calculations

Discussions with stakeholders and pretesting of the choice experiment revealed the importance of providing a description of watering cost to residents when asking them to consider alternative landscaping options (see Chapter 2). In the choice sets we included individual calculations for water use and watering cost for each lawn alternative presented, and watering cost was significant in residents' choice of lawn alternative. Accordingly, we included part worth utility estimates for watering cost in the coupled model (Table 4.2). We describe the calculation of watering cost below.

Lawn watering cost was calculated as a function of water pricing and water use with the following considerations: First, the amount of water required (mm of water per month) for maintaining a healthy lawn varies during the yearly watering period (April –

October) and was derived from City of Kelowna lawn irrigation guidelines. As shown in Table 4.4, traditional varieties of turfgrass require more irrigation than water conserving varieties to maintain a green appearance, and artificial lawns require no irrigation. Second, the amount of water required is a factor of the size of the property and the percentage of turfgrass that covers the landscapable areas of the property. Third, it is expected that the appearance of the lawn during the summer is an indicator of the amount of lawn irrigation required, where very green lawns suggest residents will use more water than those residents who maintain a mostly green lawn. Residents who allow their lawn to turn brown during the peak of summer will likely use even less water.

**Table 4.4. City of Kelowna lawn watering recommendations**

| Turfgrass type | Month | Irrigation requirement (mm per month) |
|---|---|---|
| Traditional[a] | April/May/June | 88.90 |
| | July/August | 177.80 |
| | Sept/Oct | 76.20 |
| Water conserving[b] | April/May/June | 66.68 |
| | July/August | 133.35 |
| | Sept/Oct | 57.15 |

[a] Kentucky Blue Grass, Ryegrass varieties
[b] eco-Smart Blend, Sheep Fescue, Chewings Fescue varieties

Total water use $W_{use}$ (in $m^3$) for lawn irrigation is then the product of water needed *need* in each month $m$ (in mm of water) during the watering period for each variety of turfgrass $tg$, property size (in $m^2$), the % of turfgrass in each yard, and a scaling factor $l_a$ determined from the appearance of the lawn ($l_a$ = [very green = 1.15, mostly green = 1.00, more green than brown = 0.95, more brown than green = .75]):

$$W_{use_m} = \frac{need_{m,tg}}{1000} \times property\ size \times \%\ turf \times l_a \tag{19}$$

$$W_{use} = \sum_{m\ =\ April}^{October} W_{use_m} \tag{20}$$

**Table 4.5. City of Kelowna four tiered water pricing structure**

| Volume of water ($cm^3$) | Price per $cm^3$[a] |
|---|---|
| 0 – 30.00 | $0.322 |
| 30.01 – 80.00 | $0.433 |
| 80.01 – 125.00 | $0.657 |
| 125.01 - ∞ | $1.314 |

[a] 2012 pricing in Canadian dollars

Lawn watering cost is calculated on a monthly basis according to the City of Kelowna residential water rates. The City of Kelowna water utility assigns prices for residential water use on a four-tiered pricing structure described in Table 4.5. Lawn watering cost is derived from the charges residents pay for the volume of water used $W_{use}$ during a monthly billing cycle above the base amount of water used for indoor domestic uses $D$ (an average of 19 $m^3$ per month in the City of Kelowna). To determine the additional charges residents pay to irrigate their lawn, total water used (indoor and outdoor) and the cost for this water is calculated and then reduced by the price residents would pay for their base indoor water use as follow:

Total household water use $Wh_{use}$ in a given month $m$ allocated to the price of water $Wp$ in tier $t$ provides an estimate of total household water cost $C_{total}$ accordingly:

$$Wh_{use_m} = W_{use_m} + D_m \tag{21}$$

$$C_{total_m} = \begin{cases} Wh_{use_m} \times Wp_{t=1} \text{ if } Wh_{use_m} \leq 30 \\ 30 \times Wp_{t=1} + (Wh_{use_m} - 30) \times Wp_{t=2} \text{ if } Wh_{use_m} > 30 \text{ } and \text{ } Wh_{use_m} \leq 80 \\ 30 \times Wp_{t=1} + 50 \times Wp_{t=2} + (Wh_{use_m} - 80) \times Wp_{t=3} \text{ if } Wh_{use_m} > 80 \text{ } and \text{ } Wh_{use_m} \leq 125 \\ 30 \times Wp_{t=1} + 50 \times Wp_{t=2} + 45 \times Wp_{t=3} + (Wh_{use_m} - 125) \times Wp_{t=4} \text{ if } Wh_{use_m} > 125 \end{cases} \tag{22}$$

The cost of non-irrigation domestic water use priced in the first tier can be subsequently subtracted from the total household water cost to provide total lawn watering cost $W_{cost_p}$ for the set of lawn attributes $p$:

$$W_{cost_p} = \sum_{m=April}^{October} \left( C_{total_m} - D_m \times Wp_{t=1} \right) \quad (23)$$

### 4.2.3. Okanagan surface water system

The Okanagan Hydrologic Connectivity Model divides the Okanagan Basin into 32 watersheds, 40 residual areas, five mainstem lakes, and four points of interest on the Okanagan River (Summit Environmental 2013). In our study, we limited the system modelling to those surface water sources that are directly involved in the supply and delivery of water to residents characterized by the stated preference data. The Okanagan coupled model hydrological system represents the Okanagan Lake, Okanagan River, Mission Creek, Hydraulic Creek, and the major catchments where extractions and upland reservoirs are present (e.g., McCollogh Lake, Long Meadow Lake) (Fig. 4.4). All other stream catchments and residual areas were accounted for as lumped inputs to a mainstem lake or river segment in order to balance supply and demand in the region.

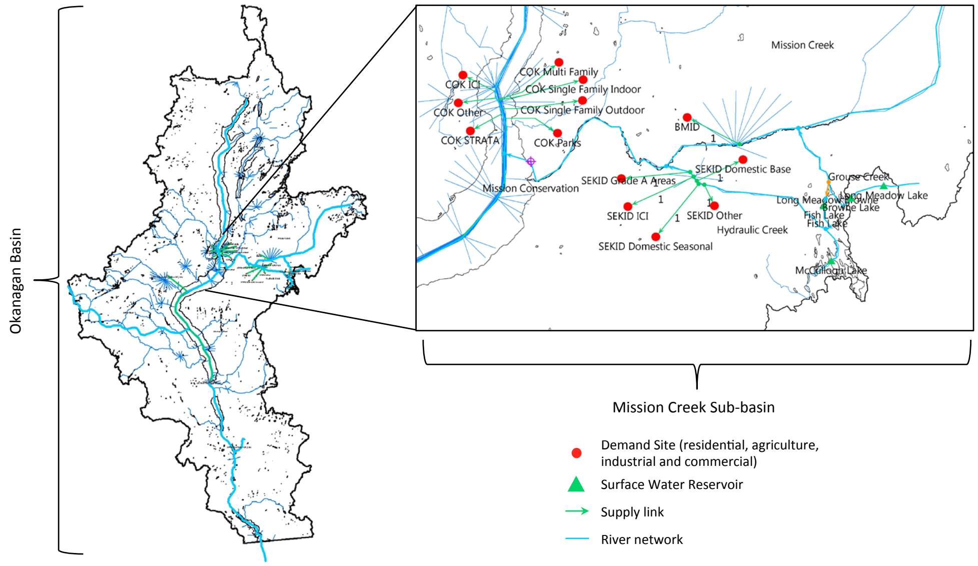



**Fig. 4.4. The Okanagan Basin in the WEAP (Water Evaluation and Planning) model. Focus on the Mission Creek sub-basin, with its water demand sites and the tributary sources supplying water use characterized by stated preference data.**

The physical properties and operational rules, as well as flow data for each mainstem river in the Okanagan coupled model, were constructed from several data sets. First, data extracted from OWAM (DHI Water and Environment 2010) provided natural streamflow data for each water intake at upland reservoir locations and net streamflow outlets of watersheds not explicitly modeled. A minimum flow requirement was included for Mission Creek to satisfy instream flow requirements for fish and habitat specified by the Okanagan Fish Water Management Tool and the Lake Operating Plan (Hyatt et al. 2009). Elevation curves for the mainstem lakes, reservoir operation rules, and physical descriptions (e.g., maximum storage capacity, assumed initial storage, maximum hydraulic outflow, net evaporation, monthly target elevations) were based on parameters obtained from the Okanagan Hydrologic Connectivity Model (Summit Environmental 2013). Finally, net evaporation from each mainstem lake and reservoir was estimated from potential evapotranspiration and precipitation data from Environment Canada prepared for the Okanagan Water Supply and Demand Project (Summit Environmental 2009).

### 4.2.4. Water demand data

Water demand data were prepared for each of the demand sites represented in Fig. 4.4 from three data sources. First, water utility data from the City of Kelowna provided demand profiles for the categories: single family indoor and outdoor, industrial and commercial, multi-family and strata, parks, and net uncategorized water use. Metered data from the Southeast Kelowna Irrigation District provided demand profiles segregated into agriculture, domestic base load and sessional water use (i.e. outdoor irrigation), industrial and commercial, and net uncategorized water use. The remaining water demand data for the Black Mountain Irrigation District were prepared from data extracts from the Okanagan Water Demand Model (Summit Environmental 2010b).

In this paper we focus on single-family outdoor water demand in the City of Kelowna represented in Table 4.6 and shown as “COK Single Family Outdoor” in Fig. 4.4. Outdoor water use currently represents 20.3% of overall water use in the City of Kelowna water service area. Across the 13,506 single-family households served, outdoor water use was annualized in the modal at 2.97 million $m^3$/yr. Lawn irrigation accounts for almost all outdoor water use in single-family households in the City of Kelowna (City of Kelowna 2009) so non-irrigation contributions to outdoor water use were assumed to be negligible and not included in the study.

**Table 4.6. City of Kelowna monthly outdoor water use variation**

| Month | Water use ($m^3$) [a] | % of annual outdoor water use |
|---|---|---|
| January | - | 0% |
| February | - | 0% |
| March | - | 0% |
| April | 152,542.00 | 5% |
| May | 346,862.00 | 12% |
| June | 497,230.00 | 17% |
| July | 754,563.00 | 25% |
| August | 811,087.00 | 27% |
| September | 331,831.00 | 11% |
| October | 72,216.00 | 2% |
| November | - | 0% |
| December | - | 0% |
| TOTAL | 2,966,331 | 100% |

[a] 2010 current accounts based on 13,506 households

Estimating changes in outdoor water demand for households in the City of Kelowna water utility service area in response to residents switching to proposed new lawn alternatives is a function of combining the multinomial logit model provided in equation (17) with the water use data provided in Table 4.6. First the relative percentage of households $H_{SQ}$ that would choose their existing lawn described by the attributes $q$ when compared to the lawn alternative $j$ with the attributes $p$ is represented by:

$$H_{SQ} = \frac{\exp\left(\beta_j^{con} + \sum_{q=1}^{Q} \beta_{jq}^{pre}\right)}{\sum_{j=1}^{J} \exp\left(-\beta_j^{con} + \sum_{p=1}^{P} \beta_p^{att} z_{jp}^{att} + \sum_{q=1}^{Q} \beta_{jq}^{pre} z_q^{pre}\right)} \qquad (24)$$

where status quo water use $SQ_{water}$ attributed to these households $H_{SQ}$ is a factor of current outdoor water use $O_{water}$:

$$SQ_{water} = H_{SQ} \times O_{water} \qquad (25)$$

Water use $H_{waterj}$ attributed to households selecting the lawn alternative $j$ is the product of the percentage of remaining households and water use required to maintain the lawn alternative $j$ with the attributes $p$:

$$H_{waterj} = \left((1 - H_{SQ}) \times SFH_{total}\right) \times \sum_{m = April}^{October} W_{use_m} z_{jp}^{att} \qquad (26)$$

where $W_{use_m}$ is the monthly water use represented in equation (19) and $SFH_{total}$ is the total number of single-family households in the City of Kelowna water utility service area. Resulting outdoor water demand when presenting lawn alterative $j$ is coded as the sum of $SQ_{water}$ and $H_{waterj}$.

### 4.2.5. Model verification

The objective of model verification was to verify the hydrological components of the Okanagan coupled model and test its parameterization against the streamflow and lake level data extracted from OWAM for the base year 2010. OWAM data were derived from a detailed hydrologic model of the Okanagan Basin developed in the MIKE SHE integrated watershed modelling system (DHI Water and Environment 2010). OWAM provided a sophisticated hydrological representation of the Okanagan basin, but OWAM calculated water demand from changes in streamflows and reservoir levels whereas in the Okanagan coupled model we estimated water demand by water service area and category (i.e. City of Kelowna outdoor water use). We compared net flows of the Okanagan coupled model with the net flows calculated by OWAM at outlets of Mission creek, Hydraulic Creek, and Grouse Creek. We also compared observed water storage in the reservoirs McCollugh Lake, Browne Lake and Okanagan Lake.

Table 4.7 lists the results of comparing the baseline scenario with OWAM results. For each tributary and waterbody we calculated the Nash and Sutcliffe Model Efficiency coefficient $R^2$ (1970) and correlation R. Matching was good for Mission Creek ($R^2$ =0.95) and Grouse Creek ($R^2$ =0.89) and satisfactory for Hydraulic Creek ($R^2$ =0.75). Matching was also satisfactory for Okanagan Lake ($R^2$ =0.73) but less satisfactory for Browne

Lake ($R^2$ =0.67) and McCollugh Lake ($R^2$ =0.22). Low $R^2$ results for McCollugh Lake and Browne Lake were not surprising due to differences in water demand data sets between the Okanagan coupled model and OWAM for these water bodies. However, these differences do not impact observed levels for the Okanagan Lake or streamflows in other tributaries, suggesting the hydrological components of the Okanagan coupled model adequately represent hydrological conditions in the basin. Overall, we consider the validated model suitable for the region of study in the Okanagan Basin and that it may reasonably be used for exploring changes in water demand due to changes in residential landscapes.

**Table 4.7. Statistical comparison of net flows and lake elevation between the Okanagan coupled model and the Okanagan Water Accounting model**

| Tributary/ Waterbody | Correlation | Nash-Sutcliffe Efficiency $R^2$ |
|---|---|---|
| Mission Creek | 0.97 | 0.95 |
| Hydraulic Creek | 0.94 | 0.75 |
| Grouse Creek | 0.85 | 0.89 |
| McCollugh Lake | 0.55 | 0.22 |
| Browne Lake | 0.60 | 0.67 |
| Okanagan Lake | 0.91 | 0.73 |

## 4.3. Scenario analysis using the Okanagan coupled model

The multinomial logit model presented in Table 4.2 and Table 4.3 provides a means to determine the preferences of residents of the City of Kelowna for attributes of residential lawns (see Chapter 2). Subsidies, turfgrass variety, the percentage of turfgrass in each yard, the appearance of the lawn during the peak of summer, and the cost of water required to maintain that lawn all influence whether a homeowner would likely choose to make alterations to their residential landscape.

Determining how residential preferences for lawn attributes translate to changes in water use requires further examination due to the contributory effect each attribute has on water use. Turfgrass variety, the percentage of turfgrass in each yard, and the appearance of the lawn during the peak of summer all contribute to the amount of water required to maintain residential lawns. The water savings anticipated from a policy targeted at lawn size reduction would therefore be uncertain until the contributing effects other attributes had on overall water use were simulated.

The Okanagan coupled model framework allows for these contributory effects to be included in the analysis and consideration of landscape changes. The multinomial logit model in the Okanagan coupled model operates as an embedded calculation, so that changes in attribute levels for lawn alternatives and the subsequent effect on residential landscaping choices are processed in WEAP automatically. We coded the part worth utility coefficients for the attributes listed in Table 4.2 and Table 4.3 as key assumptions in the coupled model, allowing us to simulate changes in residential outdoor water use under various scenarios. We coded all part worth utilities listed in Table 4.2 and Table 4.3, including subsidy (although it was only significant at the 10% level), to provide consistency with our earlier study (see Chapter 2) and so each attribute would be included in the ratio of utilities in equation 24. In addition, we coded the relationships defining water use variation in response to lawn attributes affecting residential landscapes as user-defined functions in WEAP.

In the WEAP scenario explorer user interface we programmed the ability to adjust the attributes for both the lawn alternative and status quo conditions. After programming, the levels for each attribute can be changed and the Okanagan coupled model responds by re-calculating watering cost and the likelihood of residents' choices under any of the scenarios. Adjusted water demand is similarly calculated and processed by WEAP and the corresponding changes in the hydrological system presented to the model user. Taken together, the modelling framework was prepared to provide flexibility to the user to define scenarios that affect the water use demands of the system according to characteristics of the region and the residential landscape options being considered by decision makers.

The input of different lawn alternatives and current lawn conditions provides over 9,216[1] possible configurations to be studied. Analyzing all these scenarios would be impractical and would not necessarily inform the policy options being considered to address water use for single-family residential lawns in the City of Kelowna. For the preparation of this paper, we focused on three scenarios to demonstrate the potential of the Okanagan coupled model, in each case starting with specified status quo conditions designed to represent the current lawn conditions and lawn preferences of single-family residents in the City of Kelowna.

Findings from our survey of residents (see Chapter 2) indicate that 62.2% of single-family households in the City of Kelowna reside on "averaged sized" properties greater than 0.15 acres (0.061 hectares) and less than 0.25 acres (0.103 hectares) in area. Traditional varieties of turfgrass (Kentucky blue grass, ryegrass) comprise a substantial majority (95.5%) of the residents' lawns and these lawns cover approximately 50% (37.3%) or 75% (38.1%) of the landscapeable area of their property (Chapter 2). Further, more than 85% of the residents irrigate their lawns to be either "mostly green" or "more green than brown" during the peak of summer (Chapter 2). Following these findings, we prepared two status quo variants, labelled SQ50 (representing landscapes with 50% turf, mostly green appearance, traditional turf varieties, and average sized properties with a summer watering cost of $130) and SQ75 (representing landscapes with 75% turf, mostly green appearance, traditional turf varieties, and average sized properties with a summer watering cost of $220), to use in each of the scenarios as representing existing lawn conditions. These status quo variants were used throughout the scenario analysis, effectively representing segments defined by the current landscape situation of the residents.

With the parameters of the Okanagan coupled model prepared empirically, we can now demonstrate the use of the model by simulating the adoption rate of lawn alternatives, and corresponding changes in water use, in response to hypothetical

[1] Calculated as New Lawn Size (4 levels) X New Lawn Variety (3 levels) X New Law Appearance (4 levels) X New Lawn Subsidy (4 levels) X Current Lawn Size (4 levels) X Current Lawn Variety (3 levels) X Current Lawn Appearance (4 levels)

polices aimed at reducing outdoor water use. We examine adoption rates for a 5 year period following the year 2010 as the base year for three scenarios. The first scenario is a baseline case in which existing lawn attributes are maintained throughout the simulation period. In each of the other scenarios, it is assumed that water managers propose to residents that they change their lawns to a specified alternative configuration that would conserve water use. To encourage the voluntary change, information is provided about the reduced watering costs available with the alternative water conserving configuration, together with a small subsidy for making the change. The scenarios and their parameters are listed in Table 4.8 and are described below:

- A *Baseline* scenario in which existing lawn attributes remain unchanged throughout the simulation period;

- A *Preferred Lawn* scenario, in which water managers propose a lawn alternative that matches the lawn attributes most preferred by residents in the choice experiment, based on the part worth utility coefficients set out in Table 4.2: presenting residential landscapes with lawns that cover 50% of the landscapeable area, use a water conserving turfgrass variety, and are "mostly green" in appearance during the peak of summer, with a flat subsidy of $250 for switching to the proposed lawn alternative. The summer watering cost for this alternative would be $90 for average sized properties.

- An *Extreme Water Conserving* scenario, in which water managers propose a lawn alternative that significantly reduces the fraction of turfgrass in residential landscapes and the subsequent water needed to maintain these lawns: presenting residential landscapes with lawns that cover 25% of the landscapeable area, use a water conserving turfgrass variety, and are 'more brown than green' in appearance during the peak of summer, with a flat subsidy of $125 for switching to the proposed lawn alternative. The summer watering cost for this alternative would be $30 for average sized properties.

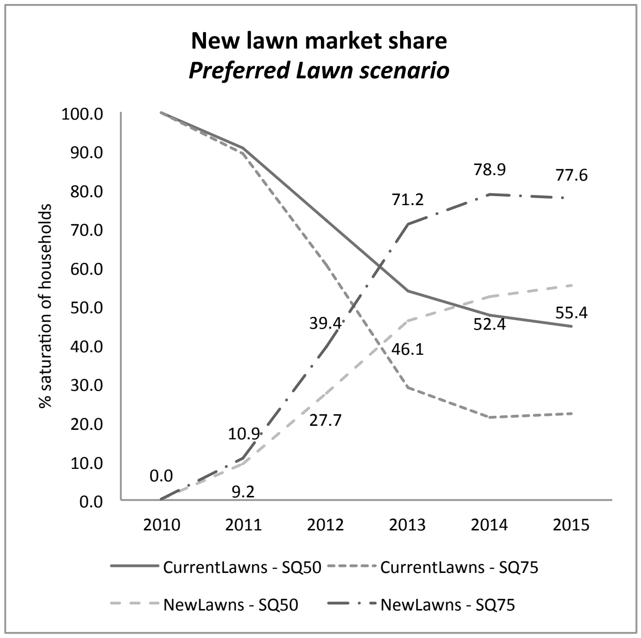
**Table 4.8. Summary of scenarios evaluated**

| Theme | Description | Lawn alternative presented | Status Quo conditions |
|---|---|---|---|
| *Baseline* | Based on the year 2010 with no change in residential landscapes | N/A | SQ50, SQ75 |
| *Preferred Lawn* | Proposes a lawn alternative that residents would most likely choose based on part worth utility coefficients | 50% turf, water conserving variety, mostly green appearance, $250 subsidy, $90 lawn watering cost | SQ50, SQ75 |
| *Extreme Water Conserving* | Proposes a lawn alternative that involves extreme changes to lawns in residential landscapes | 25% turf, water conserving variety, more brown than green appearance, $125 subsidy, $30 lawn watering cost | SQ50, SQ75 |

For each scenario we assumed a 5 year s-shaped logistic adoption curve of new lawns and evaluated the status of water allocations to the "COK Single Family Outdoor" water demand node site shown in Fig. 4.4. During each monthly time step a stochastic factor representing a random standard deviation of up to 5 from the mean was applied to the water demand calculation to induce variability and further create behavioural realism in each scenario[2]. In describing the results below, we review the proportion of households adopting the proposed lawn alternative (i.e. market share) and compare outdoor water demand in each scenario to the baseline scenario.

In presenting the results, we return to the main aim of the paper, which is to demonstrate an empirical method for incorporating human behaviour in a water resource model. Fig. 4.5 to Fig. 4.7 present the results of the simulations using the Okanagan coupled model, and show the evolution in the rate of change in single-family landscapes over time to different lawn alternatives.

[2] See (Bartholomew and Bartholomew 1967) for a discussion of stochastic models of social systems



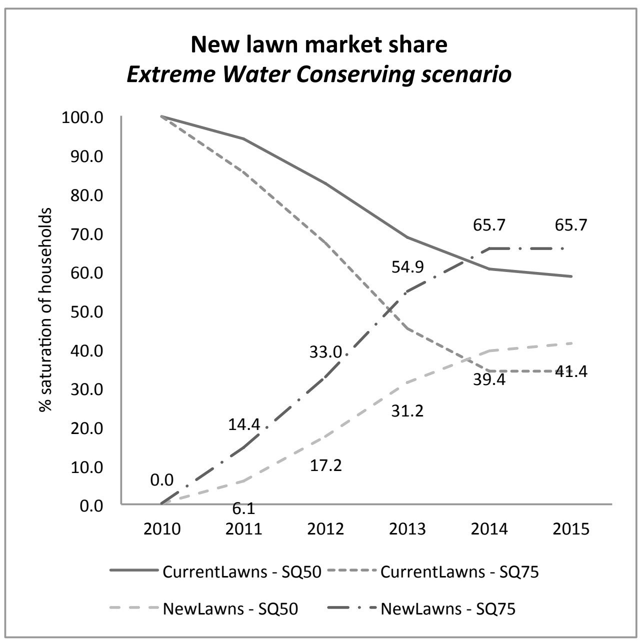




**Fig. 4.5. Lawn market share during the period 2010-2015 for the *Extreme Water Conserving* and *Preferred Lawn* scenarios**

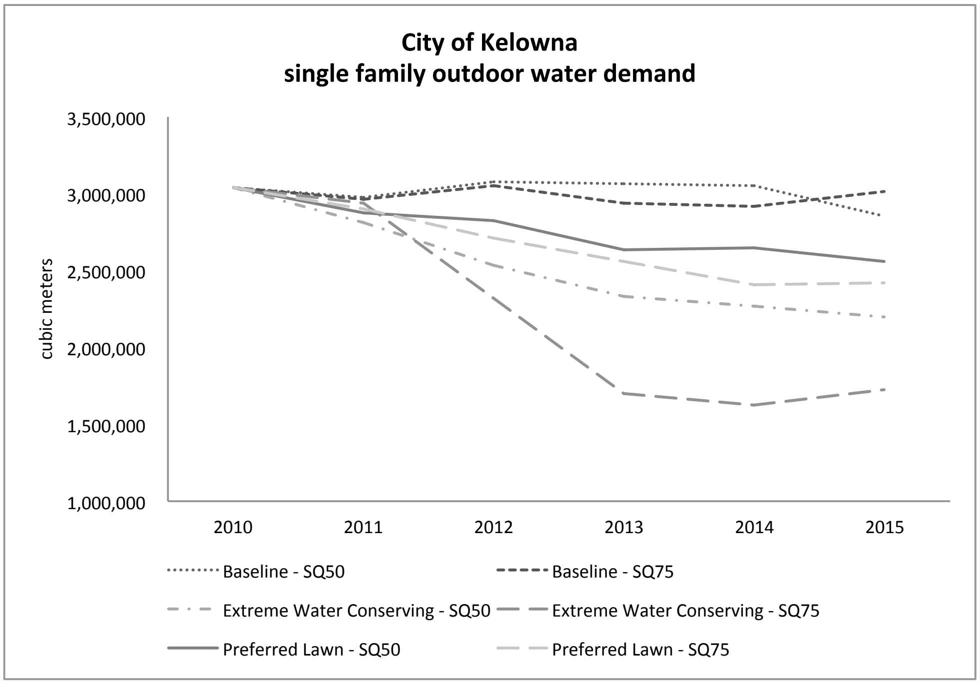
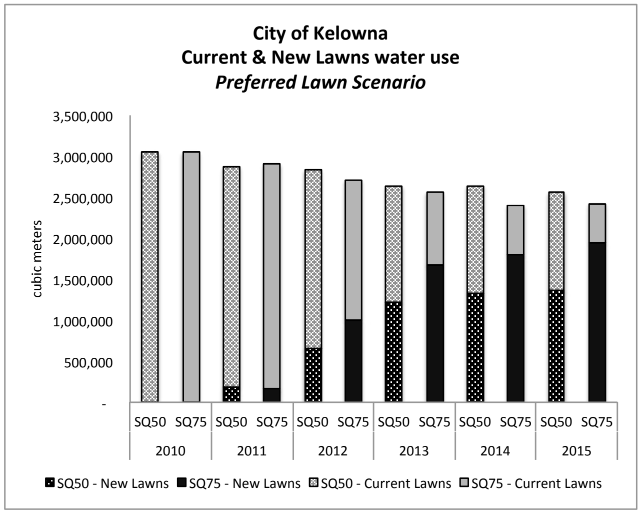



**Fig. 4.6.** **Single family outdoor water demand under the *Baseline*, *Extreme Water Conserving*, *and Preferred Lawn* scenarios during the period 2010–2015 for SQ50 and SQ75 status quo configurations**



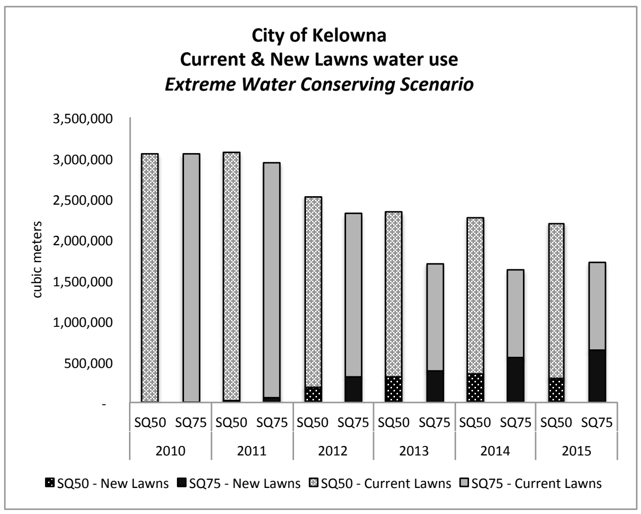




**Fig. 4.7.** **Effect of SQ50 and SQ75 status quo configurations on single family outdoor water demand for the period 2010–2015 for the *Extreme Water Conserving*, and *Preferred Lawn* scenarios**

The *Preferred Lawn* scenario increases the market share of the new lawn alternative, over the baseline, by 55.4% for SQ50 configurations and 77.6% for SQ75 configurations, while the *Extreme Water Conserving* scenario results in an increased market share of the new lawn alternative, over the baseline, by 41.4% for SQ50 configurations and 65.7% for SQ75 configurations. These results correspond with the choice model finding that the size of lawns in existing residential landscapes significantly impacts the choice of lawn alternatives, with households with larger proportions of lawns more likely to choose water conserving alternatives (Chapter 2).

Although the increases in market share are higher for the *Preferred Lawn* scenario than for the *Extreme Water Conserving* scenario for both SQ50 and SQ75 configurations, the ultimate water use savings under each scenario depend on how much water is used under the new conditions. Fig. 4.6 illustrates that despite the larger adoption rate by residents under the *Preferred Lawn* scenario, simulated savings in water use are greater for the *Extreme Water Conserving* scenario. The *Extreme Water Conserving* scenario results in water use savings, over the baseline for the simulation period, of 16.0% for SQ50 configurations and 25.6% for SQ75 configurations, while the *Preferred Lawn* scenario results in water use savings, over the baseline for the simulation period, of 8.3% for SQ50 configurations and 10.6% for SQ75 configurations. Under either scenario the status quo configuration substantially influences the amount of achievable water use savings. Also, an important message for water managers is that under either scenario and both SQ configurations, the model results indicate that considerable savings in total water use may be attained by proposing the alternative lawn configuration to residents and providing site-specific information about the potential for reduced watering costs, along with a small subsidy. Further research is needed to determine whether residents' stated preferences will translate into real behaviour in these circumstances, but the possibility could be tested with a pilot program aimed at residents with larger proportions of turf in their landscapes.

Fig. 4.7 illustrates the relative effect of SQ50 and SQ75 status quo configurations on simulated single-family outdoor water demand for the *Extreme Water Conserving* and *Preferred Lawn* scenarios. Over the simulation period 2010-2015, new lawns represented in the *Preferred Lawn* scenario account for 28.7% of total water demand for SQ50 configurations and 41.0% of total water demand for SQ75 configurations, but new lawns represented in the *Extreme Water Conserving* scenario account for just 7.6% of total water demand for SQ50 configurations and 14.8% of total water demand for SQ75 configurations. At the end of the simulation period (2015), new lawns represented in the *Preferred Lawn* scenario account for 53.2% of total water demand for SQ50 configurations and 80.2% of total water demand for SQ75 configurations, and new lawns represented in the *Extreme Water Conserving* scenario account for 13.4% of total water demand for SQ50 configurations and 37.1% of total water demand for SQ75 configurations. So again, while adoption of the proposed lawn alternative is greatest under the *Preferred Lawn* scenario, the *Extreme Water Conserving* scenario achieves greater outdoor water savings and new lawns account for a smaller proportion of total outdoor water demand under this scenario.

## 4.4. Summary and conclusion

In this paper we presented a new generation of coupled socio-hydrological modelling that contains an explicit representation of the hydrology in the Okanagan Basin and a representation of simulated human behaviour in terms of lawn preference and water use. The model is based on the system hydrology of the region and includes a behavioural model to indicate how water users would respond to proposed lawn alternatives that affect water demanded from regional water sources. This approach addresses the call by Troy et al. (2015) for creative proxies of human behaviour that lead to more robust ways of parameterizing models. Stated preference data and discrete choice models are well suited to provide this proxy, as they supply information about relationships between the characteristics of the choices water users make and the probability of those choices being made under differing scenarios. Discrete choice models can therefore be useful in improving the empirical basis of socio-hydrological models.

We demonstrated how the coupled socio-hydrological modelling framework could be used to simulate responses by individuals to proposed lawn alternatives for residential landscapes. A multinomial logit model was coupled with the WEAP system to simulate behavioural responses by residents in the study area and to estimate changes in outdoor water use. The resultant Okanagan coupled model provides decision makers with increased knowledge about residents' preferences and intended choices, which should enable managers to make more informed decisions when designing water demand policies. We agree with Bhave et al. (2014) that a socially informed water resources model is a viable tool for water policymaking. Further, the ability to work through a number of scenarios in a short period of time allows for the possible use of the Okanagan coupled model in decision making sessions among water managers, water utilities, residents, and other stakeholders to demonstrate how behaviour affects water use demand in the Okanagan Basin. Because the Okanagan coupled model is able to simulate the complex relationship between water users and the hydrological system it should be more useful to policy makers than a behaviourally uncoupled water resource model.

In preparing the scenarios, we set status quo conditions to illustrate the potential of the multinomial logit model to provide a comparison of possible scenario conditions. That is, we assumed homogeneity in the status quo presented in each scenario across all single-family residents in the City of Kelowna water service area. Although these status quo configurations closely approximate residential landscapes across the City of Kelowna, they do not fully represent the heterogeneity of these landscapes, and we caution readers to bear this in mind when considering the results. Future application of the Okanagan coupled model may include its refinement to more fully represent the heterogeneity of existing lawns. To do so will require segmenting water demand nodes by combinations of lawn features (e.g., lawn size, lawn variety, and lawn appearances) and property sizes.

The modelling results indicate that the *Extreme Water Conserving* scenario would result in the greatest reductions in outdoor water use for residents with either SQ50 or SQ75 configurations. However, this scenario presents an ambitious lawn alternative that reduces residential lawn sizes to 25% of the total landscapable area and a ‘more brown than green’ lawn appearance (of which reducing lawn sizes contributes most to overall water savings). Water policy makers could use the Okanagan coupled model to assess the trade-offs between designing policies to encourage the maximum reduction in water demand versus aligning policies with the preferences of a larger proportion of residents, by modifying the *Extreme Water Conserving* scenario to include some of the more widely preferred lawn attributes and then evaluating the overall changes in water use. For example, they might investigate the effect of lawns appearing “mostly green” during the summer or incorporating other combinations of lawn sizes and turfgrass varieties. The studied scenario alternatives and SQ50 and SQ75 configurations represent just a small subset of the more than 9000 possible configurations that remain available to policy makers.

Our findings support calls to integrate hydrology and social sciences in order to fully model the complex interactions between watershed dynamics and human behaviour (Braden et al. 2009; Wiek and Larson 2012; Carey et al. 2014; Troy et al. 2015). Further research should explore the application of discrete choice models to estimate additional social parameters affecting water demand in water resource models. This could include investigations into the adoption of water efficient technology, smart water metering and other residential information feedbacks, more sophisticated subsidy programs, and programs targeting water use in agriculture, industry and other sectors. Such models would have the capacity to explore a wide range of human behaviour interactions with water resource systems, helping to guide water policies informed by behaviourally realistic water demand simulations.

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# Chapter 5.

# Conclusion

Decision makers managing freshwater systems in the Okanagan need to balance the competing tasks of meeting growing demands for water and protecting the natural hydrological processes supporting the broader ecosystem. In the face of dwindling water supplies, they need to recognize existing water rights held by senior license holders, balance these rights with the changing water use priorities of the broader community, and maintain groundwater systems and watershed resilience. In doing all this, they must predict how climate change will affect short and long term water allocations.

At the start of my research, water policymaking in the Okanagan was strongly influenced by the use of technical models, including the previously described hydrological models, to assess the effects of policies on regional water supplies, infrastructure, and demands (Cohen and Kulkarni 2001; Cohen and Neale 2006; Langsdale et al. 2009; DHI Water and Environment 2010). After spending five years interacting with Okanagan water managers, I fully expect that technical models will continue to function as key decision support tools to inform their decision making process. My hope is that after working collaboratively with me on the research contained in this thesis, Okanagan water managers have gained a greater appreciation for the need to include representations of human behaviour in their models. It is crucial that the decision aids used for their policy decisions include behaviourally realistic estimates of changes in water demand. Water managers will need information on how proposed policies will affect specific water users in the Okanagan basin and water suppliers will need to predict water demand in order to operate and plan to meet this demand under the uncertainty of future water supplies.

In my research I aimed to address some of the above needs by developing a set of choice models representing likely choices of residential and agricultural water users affecting water use in the Okanagan and utilizing these models to examine choice behaviour and different policies affecting water demand. My research described in Chapters 2 and 3 demonstrates that choice models can be used to prepare a valuable proxy for human behaviour to inform decisions. However, as I discuss in Chapter 4, there are limits in using a choice model alone to estimate changes in water use. I therefore constructed a water resource model of the Okanagan basin and coupled it with a simplification of the resident multinomial logit model (MNL) described in Chapter 2. The resulting coupled socio-hydrological model presents a more sophisticated representation of human-water system interactions, further increasing the information available to decision makers. Below I discuss conclusions I draw from each of my papers and how they contribute to my objective to utilize discrete choice experiments to advance understanding of the interactions between human and water systems. I further comment on how the information presented in each choice model and how the results of the coupled socio-hydrological model can be used to inform water policymaking in the Okanagan.

## 5.1. Review of Papers

In my first paper (Chapter 2), I examine the pressures that the irrigation of residential lawns places on the Okanagan water supply. The paper was motived by the strong likelihood that water managers in the Okanagan will need to consider policies to stem the continued growth in outdoor irrigation (Summit Environmental 2010). This trend raises questions as to the preferences of residents toward the lawn features that account for a large portion of irrigation demand. Also, given that the Okanagan has a substantial stock of single-family homes with large lawns (Conrad 2012), decision makers need to consider how residents' preferences toward their existing lawn features factor into their decisions to alter their lawns.

To study these questions, I first conducted a survey of residential households in the City of Kelowna water utility service area, including a discrete choice experiment that presented residents with two alternative lawns and their existing lawns (status quo conditions) as described by them. I provided information on watering cost and water use for each alternative, including their current lawn configuration. In my analysis I find that many residents have preferences for smaller lawns then they currently have and that many residents have preferences for water conserving varieties of turfgrass. This finding suggests that residents' preferences may not align with existing conditions and that outdoor water use is likely higher than it would be if these residents were encouraged to make changes to their landscapes and adopt the lawn characteristics they say they prefer. I explored some of the factors that may affect residents' decisions to alter their lawns by including attributes that describe the status quo (i.e. a resident's current lawn) as predictors in the MNL model I developed. In doing so I increased that model's capacity to explain the effects status quo features have on preferences for the status quo or alternatives. Residents' existing lawn size, appearance, and variety were a significant influence on their preferences for lawn alternatives, especially for those residents with small lawns (e.g. 50% or 25% turfgrass) and water conserving varieties of turffgrass. I also investigated two incentives for encouraging lawn alterations: water pricing and subsidies. I find that water price is significant in that residents' preferences for lawn alternatives with higher irrigation need decrease with water price agreeing with other studies reviewing the relationship between water price and water demand (Nieswiadomy 1992; Renwick and Green 2000; Arbués et al. 2003). However, it is surprising to find that subsidies, at least at realistic levels to the City of Kelowna at the time of the study, have only a small influence in residents' choices of alternative lawns, suggesting that either the City of Kelowna would need to offer different levels of subsidies, provide site-specific information about potential savings in watering cots, or consider alternative policies. The study results present valuable information for decision makers in the Okanagan to understand the potential of choices by residents that would reduce outdoor water use and to explore policy options that may have been previously excluded out of concern that they would not be acceptable to residents.

In my second paper (Chapter 3), I demonstrate and discuss the use of a discrete choice experiment to investigate the preferences of farmers about various options for drought response policies in the Okanagan. This study was conducted because farmers are among the more senior water license holders in the Okanagan, and understanding their preferences is an important prerequisite for the development of an effective and acceptable strategy for reducing water demand during water shortages. I conducted a survey with farmers across the Okanagan Basin, including a discrete choice experiment that presented drought response plans with three possible policy instruments: mandatory percentage reductions in supply; granting particular types of crops priority in water allocation; and providing opportunities for water trading.

The results described in my second paper expose the interactions between crop types, farmer preferences, and policy instruments. I find that farmers, as a group, have preferences for policy instruments with moderate levels of mandatory water reductions and opportunities for trading water between farmers during times of drought. This finding provides valuable information to water managers and provincial regulators about the feasibility of various options for drought response planning in the Okanagan region. When I examine farmer preferences segmented by the primary crop cultivated (based on area of land cultivated), I find that preferences differ. Grape growers, for instance, are more likely to prefer drought response plans that feature opportunities for water trading between all water users, and ranchers may prefer drought response plans that feature high levels of mandatory water reductions. This result suggests that crop type factors into the likelihood of whether farmers might participate in water markets as well as accept water use reductions, although further investigation is required to fully explore this observation.

In my third paper (Chapter 4), I present a coupled socio-hydrological model for use as a decision support tool to inform water policymaking. This study was conducted to illustrate the coupling of a choice model with a water resource model as the development of a behaviourally realistic water model would improve understanding of the interactions between human and water systems, and the effects on water demand and supply. I prepared an Okanagan coupled model using the Water Evaluation and Planning system (WEAP) and a simplified version of the resident MNL model prepared in Chapter 2 to illustrate the interaction between residential landscape choices and regional water demand. I conducted a scenario analysis using the coupled socio-hydrological model to show the relative changes in outdoor water use following voluntary adoption of lawn alternatives designed to represent policy options Okanagan Water managers may consider. I find that the Okanagan coupled model and its embedded use of a MNL model provides a proxy of human behaviour and represents a decision support tool with significant flexibility to examine the interactions between status quo conditions, preferences for lawn alternatives, and the water savings that might be achievable through water policies designed with an understanding of resident preferences. I used the Okanagan coupled model to examine two status quo conditions (SQ50 and SQ75, described in chapter 4) in two scenarios water managers might propose to residents. I find that potential water use savings are substantial in either scenario for both SQ conditions. This example represents only a small subset of the possible configurations that water policy makers in the Okanagan could examine, using the Okanagan coupled model to assess the trade-offs between designing policies that reduce water demand and aligning policies with the preferences of residents. Overall, Chapter 4 illustrates how the use of a coupled socio-hydrological model may translate to more behaviourally realistic water use simulations, allowing for more informed policy analysis. Further studies are suggested to detail possible water savings for the multitude of existing conditions present in the City of Kelowna and to explore further applications of the presented framework to additional water management issues.

## 5.2. Limitations

The behavioural models I present in this thesis were derived from rational choice theory, and the choices observed in my discrete choice experiments were assumed to reveal the actual preferences of the individuals. As such these models are subject to the limitations of rational choice theory and discrete choice experiments. Other theories of behaviour offer alternative views that individuals do not always make utility maximizing decisions, or that their stated choices in experiments may not match the actual choices they would make in real-world circumstances. For instance, Simon’s theory of bounded rationality (1991) suggests that individuals may not act rationally for many reasons including cognitive limitations and lack of information. Social norms research posits that individual behaviour is also influenced by their perceptions of what they believe others accept, expect, or do (Douglass et al. 1977; Russenberger et al. 2011; Ostrom 2014). These factors could influence the choices individuals would make outside of the experimental setting. Survey methods used in discrete choice experiments have been criticized for relying on self-reports that are prone to response bias (Schwarz 1999) and cognition errors (Krosnick et al. 2005), and for presenting scenarios that offer no real consequences or costs (Bertrand and Mullainathan 2001). In my design I attempted to maximize the behavioural realism of my choice experiments, following criteria listed in Carson and Groves (2007) and Hensher et al. (2005), to encourage rational decisions so my results would more accurately represent real-world behaviour (Hainmueller et al. 2015). However, readers of this thesis should consider the above potential limitations of discrete choice experiments when interpreting the results.

## 5.3. Extensions

My research demonstrates a method for profiling water users' preferences that can be applied in any setting where information about those preferences could contribute to better water management policies. From a methodological basis, the individualization of the choice experiment and analysis advances stated preference techniques and their application to water management. In addition, the coupled socio-hydrological model conceptual framework I present in Chapter 4 advances the study of socio-hydrology and reinforces calls to integrate hydrological modelling and social sciences to model the interactions between watersheds and human behaviour (Sivapalan et al. 2012; Carey et al. 2014; Troy et al. 2015). Identifying, modelling, and applying constructs that represent the interactions between human systems and water systems will continue to be a major endeavour for modelling sciences, especially because of the complex dynamic nature of both systems. In the following paragraphs I offer a number of suggestions for logical and useful extensions to my research.

First, to continue the study of coupled socio-hydrological modelling the conceptual framework I prepared in Chapter 4 could be expanded to identify and include direct dynamic feedbacks between human behaviour and water hydrology. For example, direct feedback between policy options and hydrological conditions could be included in a coupled socio-hydrological model allowing a closed loop examination of the available water supply and water use behaviour. The field of socio-hydrological modelling would benefit from further application of discrete choice models to describe human behaviour in response to common water conservation policies such as incentives for water efficient technologies and residential information feedbacks (e.g. smart water meters, public information programs). Moreover, multiple choice models could be included within a single coupled socio-hydrological model to provide decision makers a tool to examine a range of human behavioural interactions with water resource systems. Coupled socio-hydrological models with multiple choice models would provide decision makers the capacity to analyse policy options in combination.

Second, additional model development is suggested to advance understanding of the findings presented in this thesis. For example, if crop type does factor in the preferences farmer have to drought response policies, then the benefits – as measured by water demand reductions during droughts – gained by introducing water trading opportunities and mandatory water use reductions could be investigated by coupling these preferences with a hydrological model which includes a detailed representation of agricultural water use such as the Okanagan Agricultural Water Demand Model (Van der Gulik et al. 2010). Additionally, as discussed in Chapter 4, the coupled Okanagan model I developed could be expanded to include parameterizing individual residential landscapes – information that was not available to me – or segmenting water demand nodes by combinations of lawn features (e.g., lawn size, lawn variety, and lawn appearance) and property sizes so that the coupled Okanagan model would more fully represent the heterogeneity of existing lawns. Doing so would refine the water use predictions presented by the coupled Okanagan model to Okanagan Water Managers.

Third, a key focus of this thesis concerns developing and applying information that would benefit water managers in the Okanagan as they consider future policies. As baseline resident and farmer preferences have now been modelled, I would direct additional study to focus on policy options aligned with these preferences. For example, how would resident preferences change in response to mandatory landscaping restrictions and how effective would these restrictions be – in terms of compliance and water use savings – in reducing water use as compared to other policy instruments, such as providing higher levels of subsidy payments? I would additionally investigate possible features of an agricultural water market to be instituted during droughts in the Okanagan. This investigation would examine the influence of market features such as particular institutional arrangements, length of trade allowed, and compensation mechanisms, on farmers' participation in the market. Ultimately, future investigations should focus on understanding and predicting behaviour affecting water resources and should bridge human and water system research. The studies in this thesis represent a step in this direction by applying discrete choice modelling and coupled socio-hydrological modelling to water use behaviour in the Okanagan, offering valuable information for decision-makers and a means for examining the interactions between human behaviour and water management.

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# Appendix A.

# Research dissemination

The contributions of this research have been disseminated in the following publications and presentations, listed in chronological order:

Conrad, S., Pipher, J., Haider, W. (2016 in review) "How current lawn attributes affect the preferences of water conserving lawn options: An individualized choice experiment in Kelowna, British Columbia." *Journal of Water Resource Planning and Management*, Submitted for Publication (Source Chapter 2)

Conrad, S., Rutherford, M., Haider, W. (2016 in review) "Profiling farmers' preferences about drought response policies using a choice experiment in the Okanagan Basin, Canada." *Water Resources Management,* Submitted for Publication (Source Chapter 3)

Conrad, S., Yates, D. (2016 in review) "Coupling stated preferences with a hydrological water resource model to inform water policies for residential areas in the Okanagan Basin, Canada." *Journal of Hydrology,* Submitted for Publication (Source Chapter 4)

Conrad, S. (2015) "Climate change attitudes", presented at the Canadian Water Works Association annual conference, Whistler, BC, 27-29 October.

Conrad. S. (2015) "Okanagan Water Allocation Policies: Drought Response Planning", presented at the BC Branch CWRA Conference: Vancouver, BC, 18-19 November

Conrad, S. (2015) "Community informed water policy in the Okanagan", presented at the SFU Blue Community Engage dialogue, Vancouver, BC June 24

Conrad, S. (2015) "Policy to address delivering water to a growing urban area that takes into account both engineering and human behaviour" presented at the Royal Canadian Institute's "*Is our drinking water at risk from urban growth? Water challenges, water solutions in a changing landscape."* water panel, Vancouver, BC, June 23

Conrad, S. (2105) "Why people matter: including water user preferences in science centric policy-making", Presented at the Resource and Environmental Management research seminar, Burnaby, BC, April 9

Conrad, S. (2014) “Agricultural drought response planning: exploring policy options with BC's Water Sustainability Act”, presented to UBC Land and Food Systems Symposium, October 24

Conrad, S. (2013). *Assessing Water Use Preferences to Water Conservation Policy and Implementation Strategies*. Victoria, BC. Simon Fraser University & Investment Agriculture Foundation of British Columbia (Source Appendix F)

Conrad, S. (2013) “Assessing The Effectiveness Of Climate Change Adaptation Policies: A Survey Of Residential Water Use Preferences”, *proceedings of the American Water Works Association Annual Conference*, Denver, CO, 10 – 13 June

Conrad, S. (2013) “Understanding Kelowna BC residential attitudes about managing climate change and drought*” J.BCWWA(2)*

Conrad, S. (2013) “Assessing the Effectiveness of Climate Change Adaptation Policies: Residential Water Use Choices ”, presented at the BC Water and Waste Association Conference, Kelowna, BC, 20 – 24 April

Conrad, S. (2013) “Building A Coupled Social-Hydrological Model For Assessing The Effectiveness Of Climate Change Adaptation Policies”, presented at the BC Branch CWRA Conference: Vancouver, BC, 5-7 March

Conrad, S. (2012). *Assessing the effectiveness of climate change adaptation policies: a survey of residential preferences*. Ottawa, ON. Natural Resources Canada. (Source Appendix C).

Conrad, S. (2012) “Exploring Stakeholder Participation In Water Adaptation Policymaking: A Survey Of Residents In Kelowna British Columbia”, presented at the PICS Climate Change Solutions: The Road Ahead annual conference, Victoria, BC, June

Conrad, S. (2012) “Decision support for the water-energy nexus: examining decision-making in the American west”, in Kenney, D. (2012) *The Water-Energy Nexus in the American West*. (Source Appendix B)

# Appendix B.

## Decision Support For The Water– Energy Nexus: Examining Decision- Making In The American West

*A variation of this chapter was published as Conrad, S.A., 2012. Decision support for the water-energy nexus: Examining decision-making in the American West, in: Kenney, D.S., Wilkinson, R. (Eds.), 2012. The Water–Energy Nexus in the American West. Edward Elgar Publishing Limited. It is included with permission of Edward Elgar Publishing Limited. I am the sole author of the text and exclusively completed and authored the data analysis, tables and figures.*

## Introduction

It is July 21, 2015, and a lower-than-predicted flow in the Colorado River has caused water levels in Lake Mead to fall below 1,060 feet for the second time in two years. Aggressive water conservation programs in Las Vegas and Phoenix, in addition to restrictions on irrigation allotments to farmers in California, have failed to reduce water demand sufficiently. If water levels continue to decline in Lake Mead, it may prove impossible to use the turbines at Hoover Dam to generate electrical power. Even though the US Bureau of Reclamation has released water from Lake Powell to raise the level of Lake Mead, water managers must soon decide between shutting down power generation and further curtailing water deliveries to Arizona and Nevada.

Meanwhile, in Texas, water reserves at the South Texas Project Electric Generating Station have dropped significantly, prompting nuclear power plant managers to request an additional 80,000 acre-feet of water be diverted from the 'Texas' Colorado River – a completely different river system despite the identical name – to replenish the reserves. Rice farmers who depend on water from this Colorado River and who are still recovering from water interruptions during last year's growing season have just received notice that continued drought conditions are expected. Unless the extreme water restrictions currently in place succeed in reducing demand on the river, the Lower Colorado River Authority, which supplies water to the rice farmers in the region and the South Texas Project, must soon decide between notifying farmers that their water contracts may not be renewed and possibly defaulting on commitments to power facilities relying on river water for cooling.

Behind these two hypothetical scenarios lies the complex decision-making problem of balancing water and energy supply priorities. Like the larger Colorado River that feeds Lake Mead, the 'Texas' Colorado River supplies water for agricultural irrigation, residential consumption and power generation. The use of rivers to provide water and power has a long history, one replete with many examples of decisions to prioritize one use over the other. For instance, not a single dam was built on the Pacific Northwest's Columbia River prior to 1933. Then, between 1933 and 1973, 13 dams were constructed on the main-stem and another 23 on tributaries (Reisner, 1986). The dams provided flood control, navigation and a more stable water supply, along with hydroelectric power, to meet the West's growing demand for energy. By the mid-1960s, nearly every river in the United States had had its waters impounded by at least one dam; however, as political motivation for dam building ran headlong into the reality of escalating construction costs, the country turned to other sources for energy. Meanwhile, in the Southwest, a rapidly expanding population saw in the region's water resources a *sine qua non* for sustaining the growth of urban centers and expanding agricultural production. Thus, in the 1960s, '70s and '80s, agricultural irrigation and urban expansion would come to have priority over power generation where water resources were concerned.

The two scenarios outlined above are closer to reality than anyone might wish. In September 2010, the water level in Lake Mead fell to 1,083 feet, a level not seen since 1937 (US Bureau of Reclamation, n.d.). And in 2009, Travis and Buchanan Lakes, managed by the Lower Colorado River Authority, dropped to their lowest elevation in 50 years (Williams, n.d.). With water supplies in such a dire state, one might conclude that the existing water management regime was inadequate. This is certainly plausible. But apart from raising alarm regarding the state of water management, the two scenarios highlight some of the key issues water and energy service providers must resolve.

The 2010s will witness how water and energy suppliers in the West balance the competing tasks of managing dwindling water supplies and meeting growing demand for electrical power that is low in greenhouse gas emissions. Future decision-making will take place against a background of looming climate change, uncertainty of supply and new greenhouse gas policies. Politicians, planners and resource managers will have to adopt new decision-making criteria, reflecting the need to take into account factors such as water-energy generation impacts, customer water use and its effect on energy/greenhouse gas emissions in urban water systems, and institutional arrangements between energy providers and water service providers (Maas, 2009). One certainty is that water and energy suppliers will need to work collaboratively if they are to continue to deliver adequate supplies to customers (Larabee & Ashktorab, 2007).

In the American West, managing energy production and water resources collaboratively posses a significant challenge for current and future decision-makers. The West's water supply will be augmented by the use of new technologies, such as desalination, many of which will require significant energy inputs. And while solar and wind power generation is growing in the region, power generation will continue to require substantial quantities of water. The effectiveness of future decisions will depend on the quality of scientific data, the reliability of support tools, the input of stakeholders, and the political commitment to act upon the outcomes of the decision-making process.

While in this context the potential for conflict is great and easy decisions are not likely, there does exist a variety of support mechanisms that can facilitate decision-making at all levels, for example, from deciding upon the most appropriate direction for water resource policy to selecting the most energy efficient water delivery strategy. This chapter focuses on how decision-support systems can assist in managing the complexity of the water-energy nexus. Its first objective is to introduce the concept of decision-support and examine its relevance to the water-energy nexus. This objective is addressed by defining this concept and offering a rationale for its use, and by providing background on the complexity inherent in water-energy management. The second objective is to discuss how decision-support can be applied to problems related to the water-energy nexus. In this regard, the focus herein is on water delivery to agricultural, industrial and residential users. This chapter focuses on water supply; however, many of the approaches discussed here are also applicable to managing the delivery of energy to these same users.

## The decision-support context

At the core of the decision-making problem is the interdependence between energy and water systems. Energy systems require substantial water inputs for generating, cooling and transporting energy to end users. Water systems also require substantial energy inputs at all stages of water delivery, from collection and treatment of raw water through transmission and distribution of supply to customers. Moreover, both water and energy systems are challenged by population-driven growth in demand, climate change, and competing resource demands on the part of agricultural, industrial and residential users (Conrad et al., 2011).

In recent years, there has emerged a growing number of studies that recognize the connection between water and energy resource use (Arpke & Hutzler, 2006; Cheng, 2002; Cohen, Nelson, & Wolff, 2004; Maas, 2009; Maas, 2010). Increasingly studied is the opportunity to manage energy demand through water policy (Cohen et al., 2004; deMonsabert & Liner, 1998). And energy is now a key factor influencing water allocation decisions (Conrad & Hall, 2009).

A recent study by the Water Research Foundation focusing on energy-related decision-making by water suppliers (Conrad et al., 2011) identified five imperatives for decision-makers, some of which are currently being aided by decision support: (1) assessing methods to control energy consumption and costs; (2) managing greenhouse gas emissions; (3) understanding the energy requirements of providing water to new developments (or users) and replacing existing water system infrastructure; (4) deciding between water demand management strategies and developing new supplies of water; and (5) evaluating options for energy recovery or generating energy within the water system.

### The need for decision-support

The need for decision-support lies in the complexity of the water-energy decision-making environment. Keeney (1982) was the first to suggest the complexity of decisions from informed consumers, employees and shareholders require greater public awareness, responsibility and accountability on the part of corporate and government decision-makers. Owing to growing public concern over greenhouse gas mitigation, water security, and energy and water resource competition, water suppliers must now take into consideration diverse — and often conflicting — viewpoints, concerns, objectives and political imperatives before deciding upon appropriate management options. As resource management problems grow in complexity, it becomes increasingly difficult for decision-makers to evaluate options without support.

In light of this complexity, Keeney's (1982) 12 factors associated with decision-making provide a useful framework for analyzing the intertwined features of the water-energy decision-making process. Ten of the most relevant factors are discussed below:

*Multiple objectives* — Policy makers often request that water suppliers achieve multiple — sometimes potentially conflicting — objectives, such as reducing greenhouse gas emissions while at the same time delivering sufficient quantities of potable water to customers. In this case, meeting one objective may result in failure to meet the other. Thus, for example, the process of treating water to ensure that it is potable may increase greenhouse gas emissions (Renou, Thomas, Aoustin, & Pons., 2008). When multiple objectives are specified, it is essential to evaluate the various options for achieving each one to ensure cost effectiveness and compatibility.

*Difficulty in identifying viable alternatives* — This may occur because either too many options exist or, unknown to water suppliers, significant investment is required before they can begin evaluating the most promising options. For example, for water suppliers, three strategies exist for reducing greenhouse gas emissions: reduce energy consumption, purchase low greenhouse gas emitting sources of power, or invest in greenhouse gas offsetting projects. However, understanding which strategy is the most appropriate requires, on their part, a firm understanding of their current energy consumption requirements, specific knowledge of the power generation facilities that provide power to their electrical grid, and a capability to evaluate potential offsetting projects.

*Intangibles* — Political and community factors greatly influence the acceptability of water management strategies and, as such, each decision may include hidden levels of public goodwill and/or support for upper levels of governance. Although it is difficult to quantify intangibles, they are often critical factors in identifying the best option.

*Long time horizons* — The consequences of today's water-energy decisions may not be apparent for years or even decades to come. Understanding the future implications of today's options is crucial to the decision-making process.

*The large number and diversity of impacted groups (stakeholders)* — Decisions often affect groups whose attitudes and preferences differ greatly. For example, while agricultural, municipal and commercial water users may all desire a stable supply, they may not share equal sensitivity to fluctuations in that supply (Rodriguez, Molnar, Fazio, Sydnor, & Lowe, 2009). Because of these differences, concern for equity among groups contributes to the complexity inherent in reaching an acceptable solution.

*Uncertainty* — It is impossible to predict precisely the consequences of each alternative; every action involves risk and uncertainty. New energy efficient technologies may fail, a new supply reservoir may fail, government reorganization may result in inefficiencies, or a new energy supply may turn out to be less reliable than existing sources. Decision-support tools must clearly indicate all assumptions and risk levels underlying each option if decisions are to be weighed adequately.

*The number of decision-makers* — One decision-maker rarely leads all major decisions. Several individuals, often in separate institutions or organizations, control critical aspects of the decision-making process, and collaboration is needed to resolve many of the most critical issues.

*Value tradeoffs* — Important decisions often involve value tradeoffs between critical aspects of the water system and options to reduce energy consumption. A decision-maker must decide the relative desirability of each option to achieve core organizational goals.

*Risk attitude* — A water supplier that is operating according to current industry standards may perform poorly in the future. Conversely, a water supplier that adopts an innovative strategy may run the risk of investing in technology that fails to become an industry standard. Understanding the risk attitude of an organization is essential to evaluating the appropriateness of accepting risk for each alternative.

*Sequential decision-making* — Decisions are almost always influenced by other earlier decisions. Decisions made today may open or close options that would otherwise be available to future decision-makers, thereby imposing constraints on the decision-making process.

Complexity cannot be avoided when making decisions; it is part of the problem as well as part of the solution (Keeney, 1982). In any case, addressing water-energy decisions is a difficult task that requires balancing benefits and costs of water supplies and power generation, a process facilitated by adopting a formal framework to guide the decision-maker (Conrad et al., 2011). Furthermore, a formal decision-making process allows for common sense to prevail, when the complexity of the water-energy nexus decision environment might otherwise prevent it.

## Approaches and examples of decision-support

Up to this point, this chapter has provided background to the decision-making context of the water-energy nexus, the elements of decision-support and the need for decision-support. Now the focus of the chapter will shift to the second objective, which is to illustrate various applications of decision-support to problems stemming from the water-energy nexus. Specifically, the focus is on decision-support applied to resolving specific issues relating to energy costs and consumption, greenhouse gas mitigation and water supply allocation. While it is not possible for a single support tool to address all the issues relating to the water-energy nexus, the approaches and examples discussed in this section offer a guide to using decision-support to manage the unique complexities of the water-energy nexus.

Water-energy nexus decisions have much in common, e.g., multiple objectives, long time horizons, multiple stakeholders, uncertainty and critical tradeoffs. Conversely, there are often differences, e.g., in the number of stakeholders, the type of objectives, the number of alternative strategies and the consequences stemming from uncertainties to be evaluated. It is these differences that determine which decision-support approach is most appropriate for any given case. To guide the discussion, I will focus on the three elements of structured decision-making cited above: (1) framing the system for consideration; (2) presenting the problem; and (3) engaging the decision-maker.

### *Framing the system*

Framing the system begins with determining its decision parameters. A popular approach to undertaking this first step is to develop a data inventory or assessment tool such as the Water Research Foundation's (www.waterrf.org) Energy Benchmark Metric Score Sheets, or the Pacific Institute's (www.pacinst.org) Urban Water to Air and Agricultural Water to Air Models. These tools are designed to collect data relating to a specific theme, e.g., energy and water consumption, and indicate the relative performance of the system with respect to that theme. For instance, the Water Research Foundation score sheets collect data on annual energy use and provide water suppliers with a means to compare energy use in their system against that of peers, as well as against their own previous performance (Carlson & Walburger, 2007). Building on this concept, the Pacific Institute models provide water suppliers with tools that quantify the energy use and air-emission impacts of urban and agricultural water systems based on user-entered data, e.g., facility annual water throughput, energy used at the facility, and sources of energy for the facility (Wolff, Gaur, & Winslow, 2004).

By increasing the quantity and enhancing the quality of information, inventory and assessment tools help water suppliers identify options for improving their water-energy performance. The Santa Clara Valley Water District used the Urban Water to Air Model to quantify the energy savings and reductions in greenhouse gas emissions resulting from water conservation efforts, as well as to direct future policy. According to their 2007 report 'From Watts to Water,' during the period 1993 to 2006, water conservation programs saved the district 1.42 billion kilowatt hours of energy and $183 million while eliminating 335 million kilograms of carbon dioxide. This illustrates that water conservation benefits both water and energy supply management. In addition, the Urban Water to Air Model identified areas for future policy initiatives, including integrating energy criteria in cost-benefit analysis frameworks and developing a formal water-energy partnership with local energy utilities to develop programs on water and energy (Larabee & Ashktorab, 2007).

### *Presenting the problem*

Using modeling and scenario tools can facilitate presenting complex, interdisciplinary water-energy issues to decision-makers. Many groups have turned to such tools for quantifying impacts, evaluating alternatives and generating user-defined 'what-if' scenarios. These decision-support systems link models and system data to create information products (graphs, reports, maps) that are designed to be read or interpreted by decision-makers (Pyke et al., 2007). It is difficult to differentiate, in any strict sense, models and scenario tools from other types of decision-support, but we can use water-energy related examples to gauge the potential of these tools with respect to facilitating water-energy nexus decision-making. For example, water suppliers in the cities of Albuquerque, Las Vegas, San Diego and Seattle have used the results from a research program, known as 'Energy and Water Quality Management Systems — EWQMS: Collaborative Project for Water System Optimization,' to develop decision-support tools to control and optimize energy use in water systems while at the same time maintaining water quality standards. First presented in a 1997 report titled 'Energy and Water Quality Management System,' this program has continued to expand and now includes a series of individual models, organizational practices and scenario aids (Conrad & Peters, 2007; Jentgen et al., 2005; Jentgen, 2003). At the heart of the program is a water system simulator and optimizer tailored to meet the specific needs of each supplier, needs that were identified during the course of consultations with decision-makers focusing on key criteria for pump operations, water supply and demand, energy costs and water quality. As shown in Figure 1, all the individual tools are integrated to provide a scenario for future operating plans aimed at reducing energy consumption and costs while maintaining water quality standards.

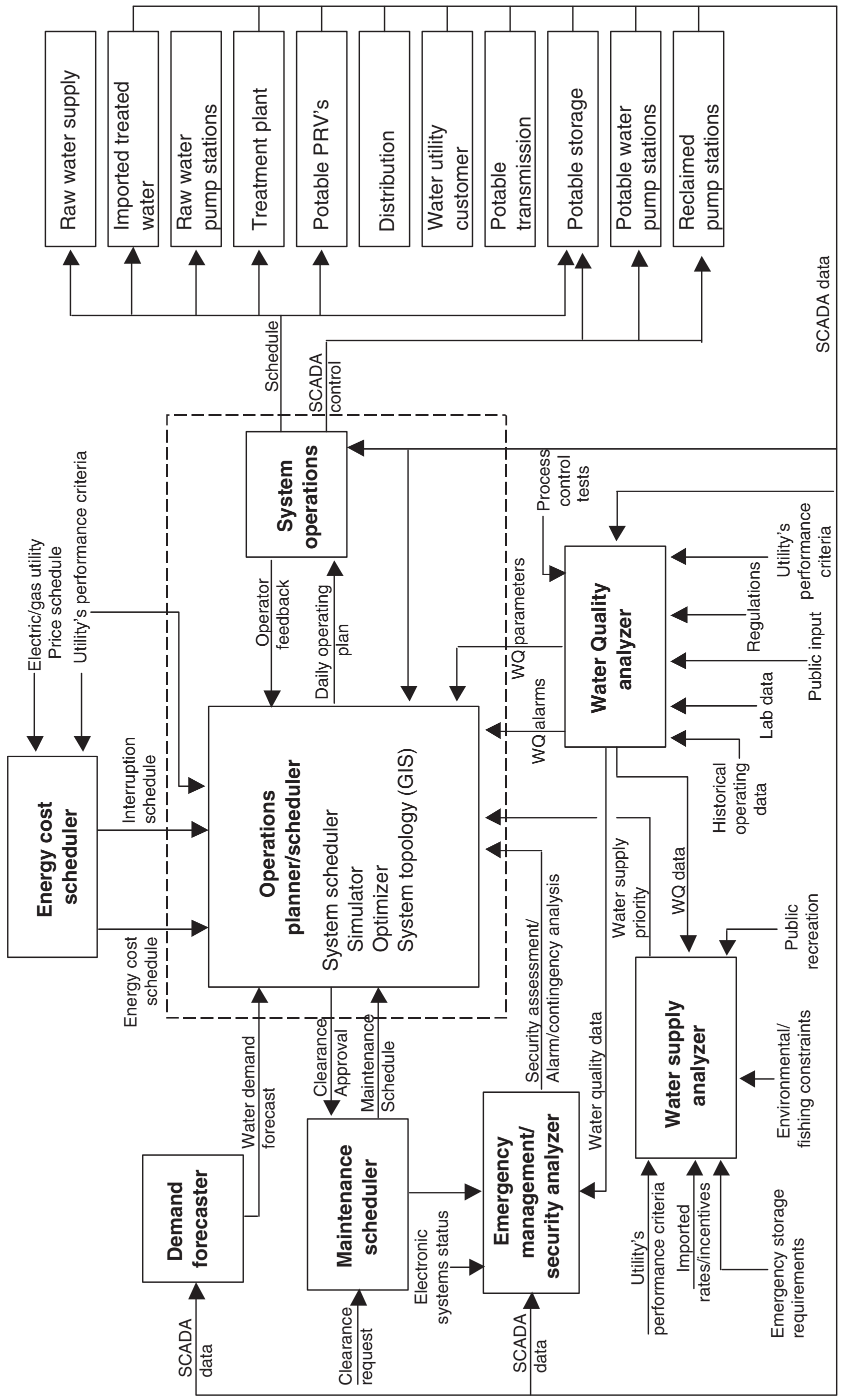


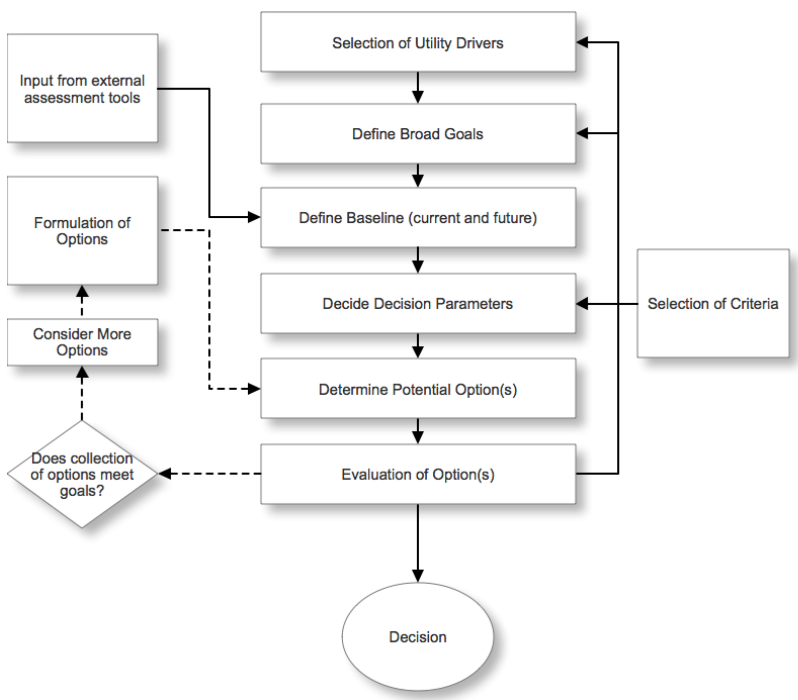

*Figure 1. San Diego EWQMS model source (Cooke & Conrad, 2005)*

Application of the EWQMS program has saved energy, reduced operating costs and improved water quality. For instance, in 2004, the San Diego Water Department, which uses an average of 42 million kilowatt hours annually (the equivalency of powering 10,000 homes), lowered energy consumption by 15% and energy costs by $1 million (Cooke & Conrad, 2005). Application of the program has also provided opportunities for greater collaboration between water and energy providers. For example, the Albuquerque Bernalillo County Water Utility Authority (ABWUA) and the state electric utility, Public Service of New Mexico, collaborate on demand response to reduce energy consumption during peak-demand days, typically the hottest days of the year. Demand response requires the water supplier to sign a contract with the electrical power provider to reduce power consumption on notice, typically 24 hours in advance, in return for lower energy rates as well as payments in compensation for power interruptions. Using the EWQMS model, the ABWUA is able to evaluate an interruption request against future operating scenarios and adjust its operations either to accommodate the request or to pay a premium for energy during the request period. During July and August of 2009, three interruptions were requested, and the ABWUA received a payment of $68,000 (Welch, 2010).

***Engaging the decision-maker***

Water-energy decisions, like many environmental management decisions, require engaging the decision-maker in an exercise to balance trade-offs among different types of impacts with a view to achieving an optimum decision (French & Geldermann, 2005). These kinds of exercises require simplified tools that recognize that a number of barriers exist between the decision-maker and the alternatives for decision resolution; as such, support tools focusing on engaging the decision-maker are oriented to identifying acceptable alternatives. Multi-criteria decision-support tools do not specify a range of predetermined alternatives; rather, they present a scenario in which a set of constraints is optimized (Pohekar & Ramachandran, 2004). The most satisfactory scenario is one that does not jeopardize another objective. The Water Evaluation and Planning (WEAP21) tool provides one example of this approach. This tool allows users to explore the outcomes of different water resource management strategies using multiple social, economic and ecological criteria (Yates, Sieber, Purkey, & Huber-Lee, 2005). The City of Portland is one of many municipalities that utilize the WEAP21 tool to evaluate regional strategies on climate change, use of alternative energy sources, and water conservation programs on energy consumption.

Additionally, recent work by the Water Research Foundation on developing a decision-support system for sustainable energy management (Conrad et al., 2011) shows how water suppliers resolving conflicting water-energy trade-offs might use multi-criteria decision-making models. Figure 2 illustrates the process used by decision-makers, like those at the city of Sunnyvale, California, to evaluate options for meeting goals of greenhouse gas mitigation, water system energy efficiency, and energy recovery based on specific environmental, economic and social criteria. Using a Microsoft Excel-based support tool, decision-makers can then select one or many options to create an energy management strategy and present that strategy to policy makers for action.




*Source: Conrad et al. 2011.*

*Figure 2.* *Multi-criteria decision process used in developing a decision-support system for sustainable energy management*

## The reality of decision-making

This chapter opened with two fictional scenarios that will, hopefully, never become a reality. If they should, decision-makers will find themselves engaged in crucial decision-making exercises aimed at developing water resource polices that will require them to select which of several support techniques should be applied to the various decision-making contexts. The current literature, however, is sadly lacking in detail regarding which specific technique would be ideal for resolving specific environmental issues, including those relating to the water-energy nexus (French & Geldermann, 2005). So, this chapter closes by identifying key — but often overlooked — elements of decision-making that one might use to identify an appropriate decision-support tool or method.

### *Influences on decision-maker behavior*

Decision-making is a human-centered process and, as such, is influenced by institutional and political processes and the knowledge and biases of decision-makers. For decision-support tools to be effective, their developers must understand the needs of decision-makers, test the outcomes of their tools against decision results, and address the role of the tool within organizational work processes (Pyke et al., 2007). Setting water and energy management policy without taking all this into account can lead to the design of policies that are ineffective or have unattended negative consequences, e.g., over-promotion of hydroelectric power to satisfy low greenhouse gas emission goals at the cost of damaging the ecology of river systems. Policy should instead be selected from a range of options, based on their ability to satisfy specific evaluative criteria including economic efficiency, public accountability and adaptability to a changing environment (Ostrom, 1999).

One goal, then, is to design decision-support that facilitates the cognitive process by which decision-makers identify such policy options. There are many theories available to guide this process including the rational planning model (Starling, 1977), theory of reasoned action (Fishbein & Ajzen, 1975), and bounded rationality (Simon, 1985). All provide input on developing a process for constructing decision-support tools based on understanding an individual's decision-making process.

Many economists view individual decision-making processes from the perspective of utility theory, which holds that individuals arrive at decisions with a view to maximizing their utility, i.e., the relative satisfaction from, or desirability of, the outcome of the choices presented, based on rational tradeoffs made among options. Rational choices are thus based on more than simple cost-benefit analysis and include satisfying multiple objectives (Simon, 1985). Decision-support, which is predicated on the concept of rational choice, might assume decision processes to be consequential and outcomes based on personal preferences to exceed predefined criteria, where in reality alternatives chosen to maximize criteria are often only the best among a list of poor alternatives (Hersh, 1999). Decision-support should instead allow decision-makers to try to improve the set of available options by changing the problem constraints. This is especially important in the water-energy nexus where the understanding of the relationship between water and energy is continually in flux, and the options available to decision-makers at the time of tool building may represent only a small set of the options currently known.

In practice, non-economists far outnumber economists, and decision-makers are also influenced by political and social factors that predispose them to select outcomes that promote the *status quo* or engage in perpetual indecision (Samuelson & Zeckhauser, 1987). It is often not the decision-maker that makes a recommendation but a political actor external to the evaluation process. Political processes that fail to inform decision-makers of the importance of the water-energy nexus can potentially restrict the range of options to be considered. However, a political process open to input from experts is more likely to take into account outputs from decision-support tools such as those discussed above.

One approach to facilitating acceptance of recommendations at the political level is to make available support tools that incorporate science in the decision-making process and to communicate the constructs of the tool to policy makers so they better understand the problem and the reasoning underling the choice of certain options (Brunner & Ascher, 1992). Water and energy scientific models are complex, so decision-support systems must be designed simple enough to be understood by non-technical participants with varied backgrounds. This constraint is one of the greatest challenges to overcome; however, if successful, it will allow the decision-maker to explore the likelihood of public support for different management alternatives (Hensher, Rose, & Greene, 2005). In this situation, decision-support tools may also help policy makers recognize opportunities to acquire resources, e.g., funds for alternative power generation facilities, while meeting the needs of constituents, e.g., by securing water supplies for agricultural districts (Pyke et al., 2007).

***Agenda setting and collaborative decision-making***

While understanding key water-energy nexus issues and the role of human relationships in shaping the decision-making process will facilitate more effective decision-support, it will not promote the widespread use of decision-support for water-energy policy. It is possible to show that providing decision-support that matches the needs of the decision-maker is more likely to lead to successful policy outcomes; however, it is also important to first set an agenda that prioritizes decision-making that is most likely to benefit from decision-support (Pyke et al., 2007).

Agendas addressing complex issues like the water-energy nexus cannot be set in isolation of the kind of multi-agency involvement required to manage resources like the Colorado River. Identifying the players and being aware of their individual needs is important in shaping agendas. One needs to first identify the organizations and institutions, along with their decision-makers, policy makers, experts and stakeholders, all of who play an important role in shaping the decision-making process (French & Geldermann, 2005). With these players in mind, one can build a team for analyzing decisions and addressing the issues at hand. Examples of this approach in the West include the Snake-Columbia River Basin task force in the Pacific Northwest and the broader Department of Energy's initiative for creating a water-for-energy roadmap and subsequent water-energy planning model.

The Snake-Columbia River Basin provides water for irrigation, power, recreation, transportation and wildlife for British Columbia and over half of Washington and Oregon. Many of the Basin's rivers are fully appropriated, and aquifers are being drawn down rapidly. At the same time, population growth in the region is placing additional demands on water resources for hydropower and residential water. In 2007, representatives from federal, state and local institutions met to discuss future energy and water requirements in the Basin and recommend focus areas for decision-support (Wichlacz & Sehlke, 2008). These areas include renewable power generation, regional modeling for integrated energy-water planning, assessment of hydroelectric energy needs demand potential, and basin-wide water allocation.

In 2005, Congress directed the Department of Energy to 'initiate planning and creation of a water-for-energy roadmap.' Over the course of five energy-water workshops, 500 stakeholders from 40 states took on the task of identifying the type of research and development required to address water-related challenges to America's energy generation and production (Tidwell et al., 2009). One outcome of these workshops was recognition of the need for a regional planning model that would help decisions-makers address the complex issues of potential energy and water shortfalls for a particular region and develop options for addressing these shortfalls. Completed in 2008 by Sandia National Laboratories, the resulting model was calibrated against water-energy use projections by water and wastewater utilities associated with the American Water Works Research Foundation and the Electric Power Research Institute, as well as power plant energy demand projections by the Energy Information Administration. With this national management model, decision-makers can project national water use demand, segmented by the North American Electric Reliability Corporation region. Recently, this includes projecting a tripling of water use by power plants in the West (Tidwell et al., 2009).

## Conclusions

Developing effective decision-support for the water-energy nexus is a challenging but worthy goal. The approaches discussed in this chapter represent only a small sample of the variety of tools available, and the vast majority of existing approaches are designed to assess the current state of systems and change scenarios. Decision-support will likely continue to attract attention as decision-support developers gain more theoretical and practical experience in delineating the cognitive processes of decision-making, along with the political processes behind the water-energy nexus. Moreover, it will be easier to select appropriate decision-support techniques as agricultural, industrial, and residential water and energy customers voice their attitudes and preferences with regard to setting water and energy agendas. These final remarks should make it clear that while there exists no common formula for arriving at water-energy decisions, there remains a great need for continued collaboration among stakeholders and advice on how to structure the water-energy conversation.

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# Appendix C.

# Okanagan Water Study Resident Questionnaire

*The following is the paper version of the Okanagan Water Study Residential questionnaire sent to survey contacts not able to access the survey website waterstudy.ca. Residents completing the paper version of the questionnaire did not participate in the choice experiment. For reference, screenshots of the choice experiments from the survey website are included in order of where they would appear in the online questionnaire. The online questionnaire was used to collect stated preference data from residents on lawn features described in Chapter 2 and complete response details are provided in Appendix D.*

# Investing in Okanagan's Water:
# What is important to you?

In collaboration with the **City of Kelowna, the South East Kelowna Irrigation District**, The Okanagan Basin Water Board, and other partners, Simon Fraser University is currently conducting a study on residential water use in the Okanagan. The survey will give you the chance to provide input on what is important to you, as your water provider plans for the future.

Your water provider will use the survey results to help them decide on future water polices and management strategies for its customers water researchers, policymakers and consumers; therefore we would truly appreciate your support.

As a **token of appreciation** for a completed survey, we will add your name to a prize draw. See page 15 for more information.

By filling out this questionnaire, you are consenting to participate. Your participation in this survey is voluntary, and you may choose not to respond to any question or terminate the survey at any time. All information that you provide in this survey will be kept strictly confidential in accordance with Simon Fraser University's research ethics guidelines. Any personal identifying information you provide will be used only to contact you in the event that you win one of the prizes. Your response will be stored offline in a secure password-controlled cache. Individual records will be identified using a code for data analysis and all records will be destroyed once the data analysis is complete. Your responses will be analyzed in aggregate and will not be identifiable in any publications.

**Contact Information**
**(See page 15)**

**Privacy Policy**
**(See page 15)**

Okanagan Basin WATER BOARD City of Kelowna Pacific Institute for Climate Solutions Knowledge. Insight. Action. BRITISH COLUMBIA Agriculture and Agri-Food Canada

## *Overview*

This survey discusses water use in the Okanagan basin, which extends from Armstrong in the north to the US border in the south.


The region is known for its dry sunny climate however the Okanagan basin also has the lowest level of precipitation of all of Canada. Each year the available amount of water is determined by seasonal fluctuations in rain and snowfall, and the storage capacity of reservoirs and aquifers.

**HOUSEHOLD WATER USE:**

In this survey we encourage you to consider your full household. Your "household" includes you and possibly other people you live with and who use water in your residence.

**1. To begin, please tell us about your home – your primary residence**

1.1 Who is your current water provider?
*Please select one response only.*

- City of Kelowna ☐
- Southeast Kelowna Irrigation District ☐
- Black Mountain Irrigation District ☐
- Glenmore-Ellison Improvement District ☐
- Rutland Waterworks District ☐
- Private Well ☐
- Do not Know ☐
- Other ____________________________

1.2 How would you describe your residence?
*Please select one response only.*

- Detached house ☐
- Multi-family house (multiple suites in a single home) ☐
- Attached house (townhouse, duplex, triplex, etc.) ☐
- Apartment/condominium ☐
- Mobile home ☐

1.3 How many people live in your residence?
*Please enter the number of individuals living in your household, including yourself.*

_________

1.4 When was your current residence built?
*Please select one response only.*

- 1970 and before ☐
- 1971-1980 ☐
- 1981-1990 ☐
- 1991-2000 ☐
- 2001-2012 ☐
- Don’t know ☐

1.5 Have any of the following rooms been renovated in your residence since it was built?
*Please select all that apply.*

- Bathroom(s) ☐
- Kitchen ☐
- Laundry Room ☐

1.6 Do you own or rent your residence?
*Please select one response only.*

- Own ☐
- Rent ☐

1.7 When did you first take up residence in the Okanagan?
*Please select one response only.*

- 1970 and before ☐
- 1970-1980 ☐
- 1981-1990 ☐
- 1991-2000 ☐
- 2001-2012 ☐
- Don’t know ☐

1.8 Are you a seasonal or part time resident?
*Please select one response only.*

- Yes ☐
- No ☐

1.9 Do you expect to be residing in the Okanagan in 5 years?
*Please select one response only.*

- Yes ☐
- No ☐

2. **Approximately how large is your property?**
*Please select one response only.*

| | |
|---|---|
| A condominium or apartment with no yard | ☐ **SKIP to 11** |
| A small urban lot or townhouse (~60 x 100 feet or 0.15 acre) | ☐ |
| An average urban lot (between 0.15 acre and ¼ acre) | ☐ |
| A large urban lot (between ¼ acre and 1 acre) | ☐ |
| A larger than average urban lot or rural property (between ½ to ¾ acres) | ☐ |
| A very large urban lot or a rural property (between ¾ to 1 acres) | ☐ |
| From 1 to 5 acres | ☐ |
| From 5 to 10 acres | ☐ |
| Over 10 acres | ☐ |

***If you answered "A condominium or apartment with no yard," skip to question 11.***

3. **How would you describe your property's landscape?**
*Please indicate which of the following features are present in your landscape.*

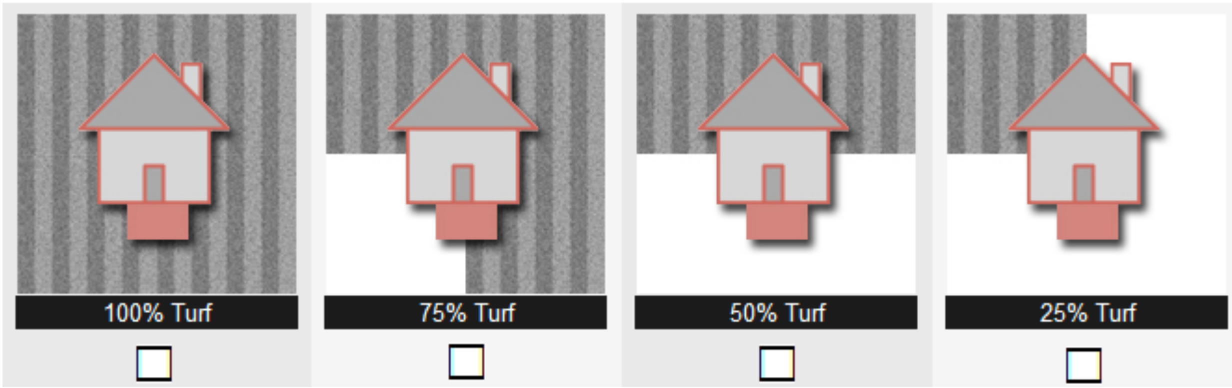
| | |
|---|---|
| Turf or lawn | ☐ |
| Traditional variety of trees, shrubs, hedges | ☐ |
| Flowers and vegetable gardens | ☐ |
| Water-conserving variety of trees, shrubs | ☐ |
| Native or natural landscape | ☐ |
| Rocks, gravel, and bare soil | ☐ |
| Other features ____________________ | |

***If you landscape does not include a "Turf or lawn," skip to question 10.***

4. **Do you hire a professional when making alterations to your landscape?**
Please select one response only.

| | |
|---|---|
| Yes, I routinely hire a landscape professional | ☐ |
| Yes, I have before but I also make many changes myself | ☐ |
| No, I make all changes myself | ☐ |
| N/A, I have not made any changes to my landscape | ☐ |

5. **Considering the yard *surrounding* your home, driveway, and patios, what percentage is covered by turf of lawn?**
*Please select the option that is closest to your lawn size.*




6. **What is the majority type of turf used in your lawn?**
*Please select one response only.*

Traditional variety of turf (Kentucky Blue Grass, Ryegrass) ☐
Water-conserving variety of turf (eco-Smart Blend, Sheep Fescue, Chewings Fescue) ☐
Artificial or synthetic turf ☐

7. **On average, how often is your lawn watered during the peak summer months (July, August)?**
*Please select one response only.*

1-2 times per week ☐
3-4 times per week ☐
5 times per week or more ☐
Almost never ☐

8. **When your lawn is watered, how is your lawn usually watered?**
*Please select one response only.*

Manually, using a hose sprayer ☐
Manually, using a hose and sprinkler ☐
Manually, using an irrigation system ☐
Automatically, using an irrigation system with timer ☐
My lawn is not watered ☐
Other ______________________________

9. **During the peak of summer, how green or brown is your lawn?**
*Please select one response only.*

Very Green ☐
Mostly Green ☐
More Green than Brown ☐
More Brown than Green ☐

**10. To what extent do you agree or disagree with each of the following statements about your landscape's appearance?**
*For each statement, please select one option.*

| | Strongly Agree | Agree | Neither Agree nor Disagree | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| I am content with my present landscape. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I would like to reduce the amount of lawn in my yard. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I would like to learn more about landscape water requirements before deciding on any changes. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I would like to eventually select more drought tolerant varieties of plants. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I do not think my neighbours would accept changes in my landscape that reduce the amount of lawn. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I would like to reduce the amount of lawn on my property, but I do not have the ***time*** to make changes. | ☐ | ☐ | ☐ | ☐ | ☐ |
| I would like to reduce the amount of water my landscape uses but I do not have the ***money*** to make changes. | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Strongly Agree | Agree | Neither Agree nor Disagree | Disagree | Strongly Disagree |

**11. Which of the following home improvements has your household taken to reduce water use in and around your residence?**
*Please select all that apply.*

- Use a low water use dishwasher ☐
- Use a low water use clothes washer ☐
- Use low flush toilets ☐
- Use low flow shower fixtures ☐
- Use an automatic irrigation timer ☐
- Use rainwater basins for outdoor irrigation ☐
- Use native or low water use vegetation in outdoor landscapes ☐
- Use a layer of heavy topsoil to improve soil water retention ☐
- Use the results of an irrigation efficiency audit to improve landscape irrigation ☐
- Reduced the amount of lawn in my yard ☐
- Replaced my lawn with a water conserving variety ☐
- Other ______________________________ ☐

**12. How confident are you in your ability…**

*Please rate your confidence on a scale from (1 = cannot identify at all) to (5 = can identify with certainty).*

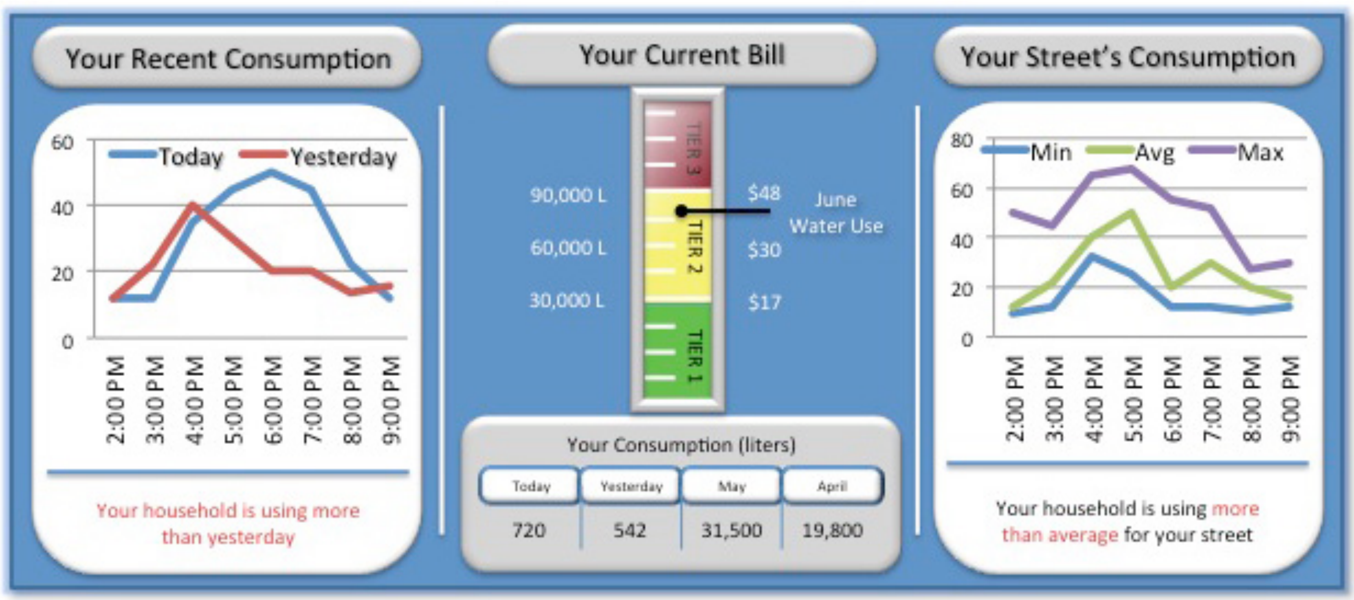
| | I cannot identify at all | | | | I can identify with certainty |
|---|---|---|---|---|---|
| ...to identify how much water is used by your household? | 1 ☐ | 2 ☐ | 3 ☐ | 4 ☐ | 5 ☐ |
| ...to identify how to reduce indoor water use by your household? | 1 ☐ | 2 ☐ | 3 ☐ | 4 ☐ | 5 ☐ |
| ...to identify how to reduce outdoor water use by your household? | 1 ☐ | 2 ☐ | 3 ☐ | 4 ☐ | 5 ☐ |

**13. Which sources of information about water and water related issues in the Okanagan do you find most trustworthy?**

*Please select up to three options below.*

Friends and family ☐
Neighbours ☐
Local news source ☐
My water provider ☐
Regional water board ☐
Provincial government ☐
Other _____________ ☐

***It is now possible to provide each household with very detailed and up-to-date information about their water consumption. The figure below shows the possible information that could be made available to you on a frequent basis.***




**14. If the above information was made available to you <u>on an in-home display</u>, to what extent do you agree or disagree with the following statements?**
*For each statement, please select one option.*

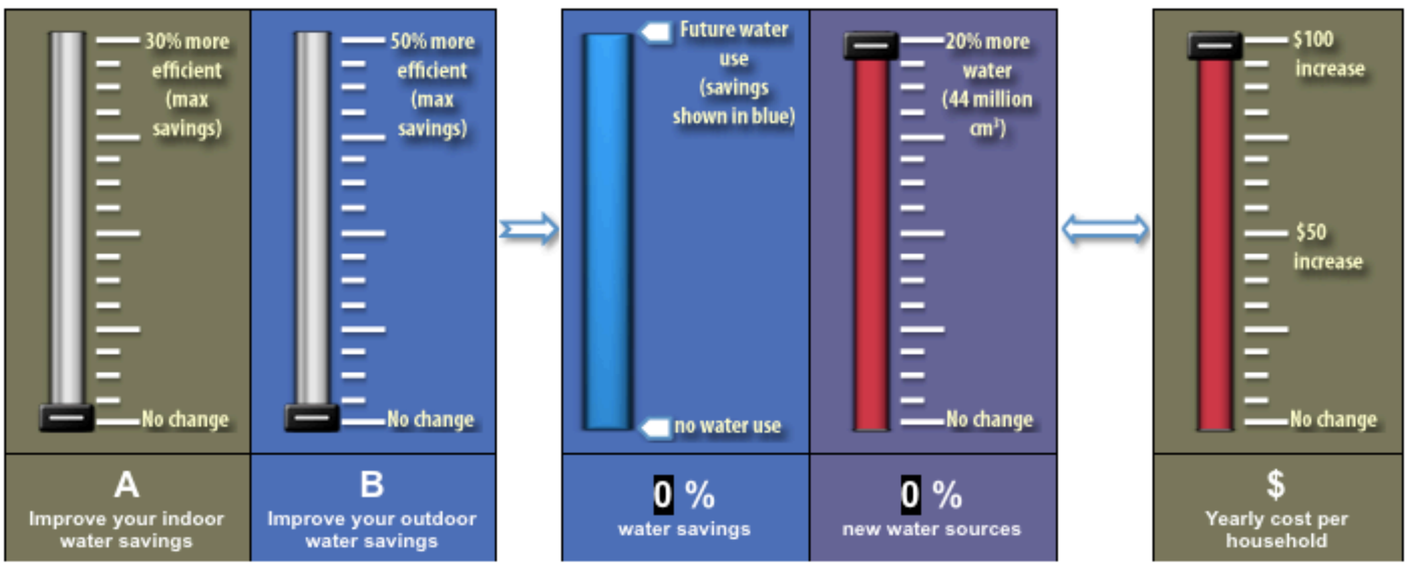
| | Strongly Agree | Agree | Neither agree nor disagree | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| I would check the accuracy of my water bill more frequently | ☐ | ☐ | ☐ | ☐ | ☐ |
| I would check my outdoor watering more frequently and think about adjustments | ☐ | ☐ | ☐ | ☐ | ☐ |
| I would purchase more water efficient appliances | ☐ | ☐ | ☐ | ☐ | ☐ |
| I would investigate and repair any water leaks I discover | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Strongly Agree | Agree | Neither agree nor disagree | Disagree | Strongly Disagree |

*Okanagan water managers* ***forecast the region will use 20% more water*** *annually by 2040. One option to meet this need is to add new water sources, such as constructing reservoirs and using more groundwater, at a cost of $100 for every household in the region. Another option is to reduce water use. Reducing water use is less costly than investing in new supplies but requires improving indoor and outdoor water efficiency.*

*Suppose every household in the Okanagan were to behave like yours, how far would you be willing to commit to change your household water use to help meet future water need? Consider the two options below (A and B) and use the sliders to indicate to what extent your household is willing to improve its water savings. There are no right or wrong answers to this question but it is important to regard it as a real-world situation, in which an investment choice is made.*

- **How far would you be willing to commit to change your household water use to help meet future water need?**

  *Use the slider bars to indicate your choice. The effect of your choices will be illustrated on the bars to the right. When you are satisfied, click next.*



# Choose your preferred landscaping - Instructions

*In the next section of this survey, you will be presented with* ***six different sets*** *of lawns to consider for your future landscape with rising water prices. Each set will consist of* ***two possible lawns and your current lawn*** *as described by you earlier.*

*Your task is to* ***pick the lawn you most prefer*** *after considering the features in each set. There are no right or wrong answers to these questions but it is important to regard them as real-world situations, in which you must make a personal investment choice.*

*Below is* ***an example*** *of what you will be asked to consider.*

**At any point during the survey you may familiarize yourself with the features of the lawn by clicking on the info buttons.**

*Price of water in 5 years* — **30% more than today**

| Lawn Features | Lawn A | Lawn B | Your Current Lawn |
|---|---|---|---|
| *% of total landscape* |  25% Turf |  50% Turf |  100% Turf |
| ***Variety*** *of turf* | Water Conserving | Traditional | Traditional |
| ***Appearance*** *during peak of summer* | Very Green | Mostly Green | Mostly Green |
| *One time* ***Subsidy*** *to reduce or replace* | $125 maximum | $250 maximum | $0 |
| ***Water use*** *over 5 years* | 140 $m^3$/year | 310 $m^3$/year | 630 $m^3$/year |
| ***Watering cost*** *over 5 years* | $60/year | $170/year | $460/year |

# Selecting a Lawn - 1 of 6

- **If the following were the only lawn options available to you, which one would you choose?** *

*Please make your choice by clicking on one of the profiles.*

| *Price of water in 5 years* | **30% more than today** | | |
|---|---|---|---|
| Lawn Features | **Lawn A** | **Lawn B** | **Your Current Lawn** |
| ***%** of total landscape* |  75% Turf |  25% Turf |  100% Turf |
| ***Variety** of turf* | Traditional | Artificial | Traditional |
| ***Appearance** during peak of summer* | More Green than Brown | Very Green | Mostly Green |
| *One time **Subsidy** to reduce or replace* | $375 maximum | $250 maximum | $0 |
| ***Water use** over five years* | 400 $m^3$/year | 0 $m^3$/year | 630 $m^3$/year |
| ***Watering cost** over 5 years* | $230/year | $0/year | $460/year |
| I would choose ➔ | ○ | ○ | ○ |

# Selecting a Lawn - 2 of 6

- **If the following were the only lawn options available to you, which one would you choose?** *

*Please make your choice by clicking on one of the profiles.*

*Price of water in 5 years* **30% more than today**

| Lawn Features | Lawn A | Lawn B | Your Current Lawn |
|---|---|---|---|
| *% of total landscape* |  100% Turf |  50% Turf |  100% Turf |
| ***Variety** of turf* | Traditional | Traditional | Traditional |
| ***Appearance** during peak of summer* | More Brown than Green | Very Green | Mostly Green |
| *One time **Subsidy** to reduce or replace* | $375 maximum | $500 maximum | $0 |
| ***Water use** over five years* | 470 $m^3$/year | 360 $m^3$/year | 630 $m^3$/year |
| ***Watering cost** over 5 years* | $280/year | $200/year | $460/year |
| I would choose ➔ | ○ | ○ | ○ |

# Selecting a Lawn - 3 of 6

- **If the following were the only lawn options available to you, which one would you choose?** *

*Please make your choice by clicking on one of the profiles.*

*Price of water in 5 years* **90% more than today**

| Lawn Features | Lawn A | Lawn B | Your Current Lawn |
|---|---|---|---|
| *% of total landscape* |  25% Turf |  75% Turf |  100% Turf |
| ***Variety** of turf* | Water Conserving | Traditional | Traditional |
| ***Appearance** during peak of summer* | More Green than Brown | Mostly Green | Mostly Green |
| *One time **Subsidy** to reduce or replace* | $125 maximum | $250 maximum | $0 |
| ***Water use** over five years* | 100 $m^3$/year | 470 $m^3$/year | 630 $m^3$/year |
| ***Watering cost** over 5 years* | $70/year | $420/year | $680/year |
| I would choose → | ○ | ○ | ○ |

# Selecting a Lawn - 4 of 6

- **If the following were the only lawn options available to you, which one would you choose?** *
  *Please make your choice by clicking on one of the profiles.*

*Price of water in 5 years* **60% more than today**

| Lawn Features | Lawn A | Lawn B | Your Current Lawn |
|---|---|---|---|
| *% of total landscape* |  50% Turf |  25% Turf |  100% Turf |
| ***Variety** of turf* | Artificial | Traditional | Traditional |
| ***Appearance** during peak of summer* | Very Green | More Green than Brown | Mostly Green |
| *One time **Subsidy** to reduce or replace* | $250 maximum | $125 maximum | $0 |
| ***Water use** over five years* | 0 $m^3$/year | 130 $m^3$/year | 630 $m^3$/year |
| ***Watering cost** over 5 years* | $0/year | $80/year | $570/year |
| I would choose ➔ | ○ | ○ | ○ |

# Selecting a Lawn - 5 of 6

- **If the following were the only lawn options available to you, which one would you choose? ***

  *Please make your choice by clicking on one of the profiles.*

*Price of water in 5 years* **90% more than today**

| Lawn Features | Lawn A | Lawn B | Your Current Lawn |
|---|---|---|---|
| *% of total landscape* |  50% Turf |  100% Turf |  100% Turf |
| ***Variety** of turf* | Water Conserving | Water Conserving | Traditional |
| ***Appearance** during peak of summer* | More Brown than Green | Very Green | Mostly Green |
| *One time **Subsidy** to reduce or replace* | $500 maximum | $250 maximum | $0 |
| ***Water use** over five years* | 180 $m^3$/year | 540 $m^3$/year | 630 $m^3$/year |
| ***Watering cost** over 5 years* | $130/year | $530/year | $680/year |
| I would choose ➔ | ○ | ○ | ○ |

# Selecting a Lawn - 6 of 6

- **If the following were the only lawn options available to you, which one would you choose?** *

  *Please make your choice by clicking on one of the profiles.*

| Lawn Features | Lawn A | Lawn B | Your Current Lawn |
|---|---|---|---|
| *Price of water in 5 years* | **90% more than today** | | |
| *% of total landscape* |  100% Turf |  100% Turf |  100% Turf |
| ***Variety** of turf* | Water Conserving | Traditional | Traditional |
| ***Appearance** during peak of summer* | Mostly Green | More Brown than Green | Mostly Green |
| *One time **Subsidy** to reduce or replace* | $250 maximum | $375 maximum | $0 |
| ***Water use** over five years* | 470 $m^3$/year | 470 $m^3$/year | 630 $m^3$/year |
| ***Watering cost** over 5 years* | $420/year | $420/year | $680/year |
| I would choose → | ◉ | ○ | ○ |

## *Your Opinion on Water Use in the Okanagan*

**15. In your opinion, how have each of the following water uses <u>changed</u> in the Okanagan region over the last 10 years?**

*For each category of water use, please select one option.*

| | Increased | Not Changed | Decreased | Do not know |
|---|---|---|---|---|
| Water used by residents | ☐ | ☐ | ☐ | ☐ |
| Water used by agriculture | ☐ | ☐ | ☐ | ☐ |
| Water used by businesses | ☐ | ☐ | ☐ | ☐ |
| Water used by parks | ☐ | ☐ | ☐ | ☐ |
| Water used by golf courses | ☐ | ☐ | ☐ | ☐ |
| Water available for the natural environment | ☐ | ☐ | ☐ | ☐ |

**16. To what extent do you personally agree or disagree with each of the following statements about <u>water use</u> in the Okanagan Basin?**

*For each statement, please select one option.*

| | Strongly Agree | Agree | Neither agree nor disagree | Disagree | Strongly Disagree | No Opinion |
|---|---|---|---|---|---|---|
| I am doing all I can to conserve water | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| My neighbours currently use more water than I do | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water conservation is an issue I am personally concerned about | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water conservation programs should include options for changing water users' behaviour | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Using technology is the only way we will permanently reduce the amount of water we use | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Strongly Agree | Agree | Neither agree nor disagree | Disagree | Strongly Disagree | No Opinion |

**17. To what extent do you personally agree or disagree with each of the following statements about <u>managing</u> Okanagan's water resources?**

*For each statement, please select one box.*

| | Strongly Agree | Agree | Neither agree nor disagree | Disagree | Strongly Disagree | No Opinion |
|---|---|---|---|---|---|---|
| Water restrictions should be voluntary rather than mandated by the government | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Regional land use and water planning is needed to manage water scarcity | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Growth of cities should be limited to manage water scarcity | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Public money should be used to develop or acquire new water resources | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| I am satisfied with the current system of water management | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water policy makers understand my priorities for water use | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Strongly Agree | Agree | Neither agree nor disagree | Disagree | Strongly Disagree | No Opinion |

**18. Which of the following statements most accurately reflects your opinion about climate change in the Okanagan the closest?**

*Please select one response only*

| | |
|---|---|
| Yes, climate change will happen, but its indications will only become apparent later | ☐ |
| Yes, climate change is happening; first indications are apparent already | ☐ |
| The statements about climate change are too uncertain. It is too early to have an opinion about it | ☐ |
| No, I do not believe in climate change | ☐ |
| Other opinion ____________________________________________ | ☐ |

**19. Have you noticed any <u>changes</u> to the following climate events in the Okanagan?**

*For each statement, please select one option.*

| | Increased | Not Changed | Decreased | Don't Know |
|---|---|---|---|---|
| The amount of rainfall during the summer... | ☐ | ☐ | ☐ | ☐ |
| The severity of winters has... | ☐ | ☐ | ☐ | ☐ |
| The frequency of water shortages has... | ☐ | ☐ | ☐ | ☐ |

**20. During short-term water scarcity events, how acceptable would each of the following water management programs be to you?**
*Please rate your acceptance of each management program on a scale from (1 = very unacceptable) to (5 = very acceptable).*

| | Very unacceptable 1 | 2 | 3 | 4 | Very acceptable 5 |
|---|---|---|---|---|---|
| Restricting the amount of water that can be used on private lawns and landscapes | ☐ | ☐ | ☐ | ☐ | ☐ |
| Restricting the amount of water that can be used on public landscapes | ☐ | ☐ | ☐ | ☐ | ☐ |
| Temporarily paying farmers to reduce water | ☐ | ☐ | ☐ | ☐ | ☐ |
| Restricting the amount of water that can be use by industry and businesses | ☐ | ☐ | ☐ | ☐ | ☐ |
| Allowing local lakes and reservoirs to drain | ☐ | ☐ | ☐ | ☐ | ☐ |
| Reducing the amount of water available for wildlife and fish habitats | ☐ | ☐ | ☐ | ☐ | ☐ |

*Imagine that in the not too distant future, you receive a notice from your water provider that spring snowpack levels are low, and that the seasonal outlook calls for a dry and hot summer, with* ***the Okanagan expected to receive 35% less rainfall than average.***

**21. During the resulting summer, how much would you be willing to reduce your household's water consumption in each of the following categories?**
*For each statement, please select one option.*

| | No reduction 0% | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | Stop this activity 100% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Summer lawn watering | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Length of showering or bathing | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Frequency of flushing toilets | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Frequency of using a dishwasher | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Frequency of using a clothes washer | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**22. Now consider the appearance of your community during the same summer. How disturbing would it be to you if public green spaces turned brown?**
*Please select one response only.*

- Very disturbing ☐
- Slightly disturbing ☐
- Neither disturbing nor not disturbing ☐
- Not disturbing ☐
- Not at all disturbing ☐

**23. During the same summer, how disturbing would it be to you if <u>private</u> green spaces turned brown?**
*Please select one response only.*

- Very disturbing ☐
- Slightly disturbing ☐
- Neither disturbing nor not disturbing ☐
- Not disturbing ☐
- Not at all disturbing ☐

> *Some future scenarios suggest that due to climate change the Okanagan Region could **continually receive about 20% less precipitation during the summer months.** In such a situation, there may not be enough water for all water uses and policymakers may consider prioritizing the types of uses of water.*

**24. For each of the following water uses, please indicate how <u>important</u> each is for the Okanagan basin in times of water scarcity?**
*Please rate how beneficial each use of water is on a scale from (1 = Not very important) to (5 = Very important).*

| | Not very important 1 | 2 | 3 | 4 | Very important 5 |
|---|---|---|---|---|---|
| Water for Agriculture (e.g., food or feed crop production, livestock) | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water for Municipal landscape Irrigation (e.g., community parks, municipal golf courses) | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water for Recreation (e.g., rafting, fishing, boating, swimming, skiing, scenic viewing) | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water for Wildlife and the Natural Environment (e.g., as part of fish and wildlife habitat, forest health, in-stream management, and other natural uses) | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water for Household Indoor Use (e.g., drinking, cooking, shower, laundry, dishwashing, toilets) | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water for Private landscape irrigation (e.g., lawns and gardens for private homes and business) | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water for Commercial and Industrial Use (e.g., commercial manufacturing, mining, and private golf courses) | ☐ | ☐ | ☐ | ☐ | ☐ |

## *Demographics*

**25. Are you responsible for paying your water utility bill?**
*Please select one response only.*

Yes ☐
No ☐
I do not receive a water utility bill ☐

**26. What is the nearest street intersection to your residence?**
*Please enter the two cross streets of the nearest intersection to your residence*
____________________________ and______________ ______________

**27. What is your gender?**
*Please select one response only.*

Female ☐
Male ☐

**28. Which of the following age categories describes you?**
*Please select one response only.*

Under 20 ☐
20 to 24 ☐
25 to 34 ☐
35 to 44 ☐
45 to 54 ☐
55 to 65 ☐
65 or over ☐

**29. What is the highest level of education that you have completed?**
*Please select one response only.*

Less than high school ☐
Completed high school ☐
Some post secondary education
(post secondary not completed) ☐
Trades or non-university certificate or diploma ☐
Completed university ☐
Post graduate degree ☐

**30. Which of the following categories best describes your pre-tax annual household income?**
*Please check the box that corresponds with your answer.*

- $19,999 or less ☐
- $20,000 to $39,999 ☐
- $40,000 to $59,999 ☐
- $60,000 to $79,999 ☐
- $80,000 to $99,999 ☐
- $100,000 to $125,999 ☐
- $130,000 to 149,999 ☐
- $200,000 to $249,999 ☐
- $250,000 or more ☐

**31. Are you retired?**

*Please select one response only*

- Yes ☐
- No ☐

## *Last Words*

**If you have any suggestions or additional comments regarding this survey, we would appreciate to know about it.**

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Thank you for completing this survey. As a token and as a token of appreciation for completing the survey you qualify to enter your name into a prize draw to win a $250 gift card to Home Depot or 1 of 3 $50 cash card prizes.

To be considered for the draw, please provide your contact information. Any personal identifying information you provide will be used only to contact you in the event that you win one of the prizes and will not be associated with your answers.

**Name: ______________________________**

**Address: ____________________________________________________**

____________________________________________________________

**Postal Code: _____________**

# Appendix D.

# Assessing The Effectiveness Of Climate Change Adaptation Policies: A Survey Of Residential Preferences

*The following was previously published as Conrad, S. (2012). "Assessing the effectiveness of climate change adaptation policies: a survey of residential preferences." Ottawa, ON. Natural Resources Canada.in support of this thesis at the conclusion of the resident landscape survey presented in Chapter 2. I was the sole author of the work with data analysis support provided by Joel Pipher.*

SFU SCHOOL OF RESOURCE AND ENVIRONMENTAL MANAGEMENT

# Assessing the effectiveness of climate change adaptation policies: a survey of residential preferences

## OBWB 11-010

*Project Technical Summary – September 2012*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## Report Summary and Organization

This technical report summarizes data and analysis results for the Regional Adaptation Collaborative Project - *Assessing the effectiveness of climate change adaptation policies: a survey of residential and farmer preferences*.

This report is organized in three sections:

Section 1: ***Overview and Highlights*** presents a synopsis of the study results

Section 2: ***Methodology*** discusses the methodologies and frameworks used to conduct the study

Section 3: ***Detailed Data Results*** presents complete outcomes from each component of the study questionnaire

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***List of Tables***

# 1. Overview and Highlights

The purpose of this project was to survey water users in the Kelowna, BC area to determine public perceptions and preferences of water demand management alternatives and to gauge which alternatives the community would most readily accept. As policymakers develop new water management strategies for climate adaptation, it is crucial that proposed solutions will result in real changes to water consumption. This project uses survey methods to estimate the "human behaviour" component in water management. Internet surveys assess the preferences of water users for different water conservation and demand management policies, using the most up-to-date social science techniques. Information from these surveys:

- Identify water policy alternatives for achieving management goals in the Okanagan Basin that can be applied generally;
- Survey water users in the Kelowna, BC area to determine preferences for water demand management measures;
- Determine water user preferences for water policy alternatives using stated preference choice analysis;
- Develop a set of quantitative consumer response data that can be built into the Okanagan Water Demand Model and a framework for quantifying data in other places this model is being used;

Survey responses from 841 domestic water users in the Kelowna, BC area provided several climate adaptation themes. First, respondents generally believe that climate change is occurring in the Okanagan, winters are less severe and water scarcity severity has increased in the last 10 years. In the short term, respondents prioritize water use for personal health, agricultural irrigation, and water for the environment over landscape watering. To address long-term water scarcity, respondents prefer a combination of water use behaviour changes, investing in new water supplies with public dollars, and managing the growth of cities. Respondents were not adverse to water restriction mandates but do find draining local lakes and reservoirs and reducing the amount of water for the environment unacceptable.

Focus groups illustrated a general lack of consideration for water and climate policy measures in the region. For instance, only 1 out of the 25 residents present at the various focus group meetings had reviewed their water bill in the last year and many commented that water shortages were not an issue of climate but due to Canada water treaties with the United States. Farmer focus groups expressed a strong willingness to work with water providers on water efficiency measures with the assurance that efficiency gains would not be allocated to other uses.

Focus groups also revealed that while there are numerous climate policy and management options, regional understanding of these options is key. Overcoming the lack of awareness is needed before options can be proposed or even understood enough by water users to form a preference. The level of understanding of policy options led to the elimination of several from the study (such as top soil augmentation, water reuse, xeriscaping policies, and remote irrigation scheduling), as they were not well understood and or mistrusted by residents and farmers.

A majority of respondents are willing to pay to invest in new water supplies to meet future water demands and are willing to balance future need by reducing indoor and outdoor water use. Respondents did not respond to lawn replacement subsidies but did respond to additional, and personalized, water use information. Further data observations are provided below and in section 3 of this report.

### *Demographic Observations:*

Demographics of respondents represent City of Kelowna residential and South East Kelowna Irrigation District domestic water users. The mean respondent:

- owns a detached home (on an ¼ acre lot) with 2.75 individuals living in the residence;
- has lived in the region for 20+ years;
- is a permanent resident and expects to continue residing in the region;
- is between the ages 45 to 65;
- has a household income between $60,000 and $100,000;
- has a trade or non-university certificate or diploma;
- has a yard with a lawn, traditional varieties of trees and plants, a garden, and some rocks or bare soil with only 23.7% of respondents indicating they utilize water conserving varieties of trees, shrubs and other plants;
- has a traditional variety (Kentucky Blue Grass, Rye grass) of lawn that makes up between 50% - 75% of the yard;
- has hired a professional landscaper in the past but primarily performs most of their own landscape changes;
- waters their lawn, during the summer, for 60 minutes between 3-4 times a week;
- uses an automatic sprinkler to water their lawn and considers their lawn to be between "mostly green" and "more green than brown" during the peak of summer;

### *Attitudinal Observations:*

The questionnaire contained numerous attitudinal questions on climate change, water use, drought management and policy, and important water uses. Some of the more interesting results are presented below.

**Landscapes:**

- Residential water users surveyed are content with their present landscape (see Table 20) but would like to learn more about water use before making future changes. Respondents would like to include drought tolerant varieties of plants in their landscape if they had the money or time to do so.
- Contrary to initial suppositions, only 10.3% of respondents "strongly agree" or "agree" with the statement that their neighbours <u>would not accept</u> changes in their landscape that reduced the amount of lawn. These results may suggest that residents feel their neighbours would accept changes in their personal lawn size. However, it is unclear whether Kelowna area residents consider their neighbours' opinion in making changes to their personal landscape.

**Water use and information sources:**

- Respondents felt confident in their ability to reduce indoor and outdoor water use, more confident in reducing outdoor water use than indoor, but less confident in identifying <u>how much</u> water is used (see Figure 15).
- Respondents trusted local water providers, local news sources, and regional water boards as a source of water information more than neighbours, family, and the provincial government.

- When presented with options to have more metered information about their water use, respondents "strongly agreed" with statements about investigating and repairing leaks and checking the accuracy of their water bill, but were "neutral" toward purchasing more water efficient appliances.
- About half of respondents indicated that they believe "water used by residents" (55.5%), "water used by business" (41.3%), and "water used by golf courses" (45.5%) have increased in the Okanagan over the last 10 years (see Figure 20). Whereas 35.3% of respondents feel that the "water available for the natural environment" has decreased over the last 10 years.
- A large portion of respondents (19.6% "strongly agree" and 59.8% "agree") believes that "water conservation programs should include options for changing water users' behaviour." Most respondents "agree" (59.8%) or "strongly agree" (19.6%) that "water conservation is an issue I am personally concerned about."
- Indicating possible support of mandated water restrictions, over half of respondents "disagree" (39.3%) or "strongly disagree" (13.4%) with the statement "water restrictions should be voluntary rather than mandated by the government" (see Figure 22).
- Respondents were willing to reduce their personal water use by an average of 44.2% during times of severe water scarcity, with a preference toward reducing the use of a dishwasher and lawn watering. Not surprisingly, reducing water for personal care (clothes washing, flushing toilets, and showering and bathing) was less preferred.
- However, over half of the respondents "agree" (11.7%) or "strongly agree" (46.3%) that "public money should be used to develop or acquire new water resources."

**On climate and specific management/policy options:**

- The majority of respondents (64.9%) believe that climate change is occurring presently.
- Half of respondents (51.5%) believe that "the severity of winters has decreased" and (38.6%) believe that "the frequency of water shortages has increased" in the Okanagan.
- More than 2/3rds of respondents find "restricting the amount of water that can be used on private lawns and landscapes" and "restricting the amount of water than can be used on public landscapes" to be acceptable (see Figure 24).
- Conversely, respondents indicated that "temporarily paying farmers to reduce production," "allowing local lakes and reservoirs to drain," and "reducing the amount of water available for wildlife and fish habitat" to be unacceptable (see Figure 24).
- While most respondents (>80%) indicated they were personally concerned with water use, a large portion of respondents (>47%) indicated that they would find "brown" public green spaces "disturbing" and a larger portion of respondents (>51%) indicated that they would find "brown" private green spaces "disturbing." This may indicate that residents are more accepting of "brown" public spaces than "brown" private spaces.
- The majority of respondents indicated that "water for agriculture," "water for wildlife and the natural environment," and "water for household indoor use" are important for the Okanagan in times of water scarcity (see Figure 29).

**Choice experiment(s) results:**

- Results indicate a negative preference for smaller lawn sizes.
- Residents may be considering water use in their landscapes as respondents indicated a positive preference for artificial and water conserving varieties of turf.
- Lawn replacement subsidies do not appear to be significant nor influence lawn choices.
- "more brown than green" lawns, as expected, were least preferred, however very green lawns were also negatively preferred by respondents. This could indicate a consideration of water use in selecting landscape features and or a dislike for extreme lawn conditions (e.g. very brown or very green).
- Respondents indicated they favour balancing personal investments in indoor and outdoor water efficiency with new investments in water supplies to meet future water demands. Respondents prefer to invest in 11.26% improvements in water use reductions and 8.74% in new water supplies at a yearly cost of $44 per household. Which notably is less than the provincial goal of reaching 33% improvements in water use efficiencies by 2020.
- Respondents prefer to invest in outdoor water efficiency improvements to investing in indoor improvements.
- Respondents were willing to pay a marginal cost of $-2.98 for each % unit of indoor water saved, greater than their willingness to pay for outdoor water at $-1.96 for each % unit of outdoor water saved.

## 2. Methodology

This section outlines the project's approach to survey a statistically representative sample of Kelowna, BC water users to reveal their preferences for water use and climate adaptation policies, and understand how respondents value various uses of water under possible climate change scenarios. This section also discusses how respondents were asked to make choices about their personal landscape or make trade-offs between their household water use and future expansion in water supply systems.

Data collection occurred in two stages: Focus groups were conducted in Kelowna, BC to gauge current water perceptions and to assist in the development of the surveys that would follow. In the second stage, a residential and farmer questionnaire was developed for administering via custom-developed web sites. The custom web sites present the choice experiments, question users on their current water use, assess respondents attitudes and views on climate change, regional water use, drought management policies, as well as collect demographic information.

### *Areas of Focus*

The project began with a focused review of water demand management and conservation literature, including previous RAC work, identifying the water management issues in the region and alternatives for addressing these issues. This review informed the development of a list of discussion points and was reviewed at the first technical stakeholder workshop.

Key water concerns and management alternatives were then compiled into a summary list of attributes for possible inclusion in the project's choice experiments. Alternatives evaluated included items such as changes in watering frequencies, reduction in urban water use, changes in the appearance of the urban environment, irrigation scheduling support, rebates on water efficient technologies and the use of water budgets. Many options were eliminated from consideration during subsequent technical workshops, however the complete list of attributes is included in Appendix A in support of future research and water management programs. Final selection of alternatives is discussed below.

### *Focus Groups and one-on-one Interviews*

Multiple one-on-one interviews with regional technical and context stakeholders and five focus group workshops were conducted as part of this project. Three non-technical focus groups were conducted with regional residents and farmer groups and two technical focus groups were conducted with stakeholders representing water providers, regional water management and governance, agricultural water management, and the local academic community.

Two important outcomes of the focus group process occurred. This first was the identification and prioritization of key issues and applicable policy options. The second was an assessment of the understanding of these options by water users.

Significant changes to the study approach resulted from this process, highlighting the importance of thorough review and testing. Data obtained shifted the focus of the study from irrigation and appliance technologies to a landscape focused study for residents and a land management study for farmers.

### *Choice Experiments Design and Implementation*

One of the key objectives of this project was to undertake a behavioural evaluation of water use at different levels of management alternatives. The project accomplished this by evaluating future water use as expressed by representative sample of Kelowna, BC water users.

The project used stated preference surveys to examine decision influences by presenting water users with hypothetical, but realistic situations that may influence their water consumption. The research team constructed a discrete choice experiment (DCE) and a continuous choice experiment (CCE) to identify behavioural responses to the various demand management alternatives prioritized in the proceeding focus group sessions.

Choice experiment methods were chosen as they allow respondents to simultaneously evaluate different alternatives, and address associated trade-offs in a comprehensive fashion. Choice experiments are used widely in resource management problems and environmental valuation settings (Adamowicz et al., 1998), as well as in limited water resource contexts (Haider and Rasid, 2002; Willis et al., 2005; Barton & Bergland, 2010, Thacher, 2011). However this project represents the first known application of choice experiments in a process designed for eventual integration with technical water demand models. Results from this project will be used to construct a robust behavioural decision support system in a different but related project in 2013.

The research team designed and implemented a choice experiment using the following steps:

1. <u>Adapt key alternatives for application in a survey</u>: This step involved the translation of technical alternatives to variables that can be presented to survey respondents. The project completed this task by working with technical experts and through extensive testing. Initial options were reviewed and prioritized in technical focus groups and refined in residential and farmer non-technical focus groups. One-on-one testing further refined the attributes resulting in the choice experiments described in step 2.

2. <u>Design the survey instrument, including the stated preference choice sets</u>: The project utilized the prioritized list of alternatives from step 1 to develop a residential and farmer questionnaire. The primary purpose of the questionnaire is to present the stated preference choice experiment. Design of the questionnaire included preparing questions to collect current water use information as well as "warm" respondents to the concepts contained in the choice experiment. Other questions were included to capture attitudinal covariates and respondent values on climate change, various water uses, drought management, and personal and public water use. Careful considering was given in developing the questionnaire to follow social science best principles including those found in Dilman (2007) *Mail and Internet Surveys: The Tailored Design Method* and Vaske (2008) *Survey Research and Analysis: Applications in Parks, Recreation and Human Dimensions.*

   Three choice experiments were developed for the project: two residential and one farmer. Development of the farmer questionnaire and experiment provide a foundation for data collection as part of an Agricultural Environment and Wildlife fund project concluding in 2013. The residential experiments are described below.

DCE – Discrete Choice Experiment

In the first choice experiment, respondents with lawns and tiered water rates (i.e. City of Kelowna residents) were asked to consider the following scenario:

> *In the next section of this survey, you will be presented with six different sets of lawns to consider for your future landscape with rising water prices. Each set will consist of two possible lawns and your current lawn as described by you earlier.*
>
> *Your task is to pick the lawn you most prefer after considering the features in each set. There are no right or wrong answers to these questions but it is important to regard them as real-world situations, in which you must make a personal investment choice.*

The scenario was developed based on outcomes from earlier focus groups and consideration of multiple residential water use alternatives. Focus groups revealed that while there are numerous climate policy and management options, regional understanding of these options is key. Early results indicated that overcoming a lack of awareness is needed before options can be proposed or even understood by water users to form a preference.

As mentioned earlier, the level of understanding of policy options by regional water users led to the elimination of several alternatives from consideration (such as top soil augmentation, water reuse, xeriscaping policies, and remote irrigation scheduling). One such option, service agreements, was eliminated from the study due to possible misperception by respondents. Service agreements, the contractual act of entering into an agreement with water providers to provide water at a reduced rate in exchange for committing to reduce water, was tested extensively with focus groups. While most could relate the concept to other personal contracts (such as mobile phone contracts), many lacked the ability to form a rational decision having no prior knowledge or experience applying service contracts to water provisions.

After careful consideration of private and public perceptions of water use the project settled on a scenario centred on the greatest area of household water use, outdoor lawn irrigation. Figure 1 illustrates the choice presented to respondents to assess respondents' willingness to pay for personal lawn choices.

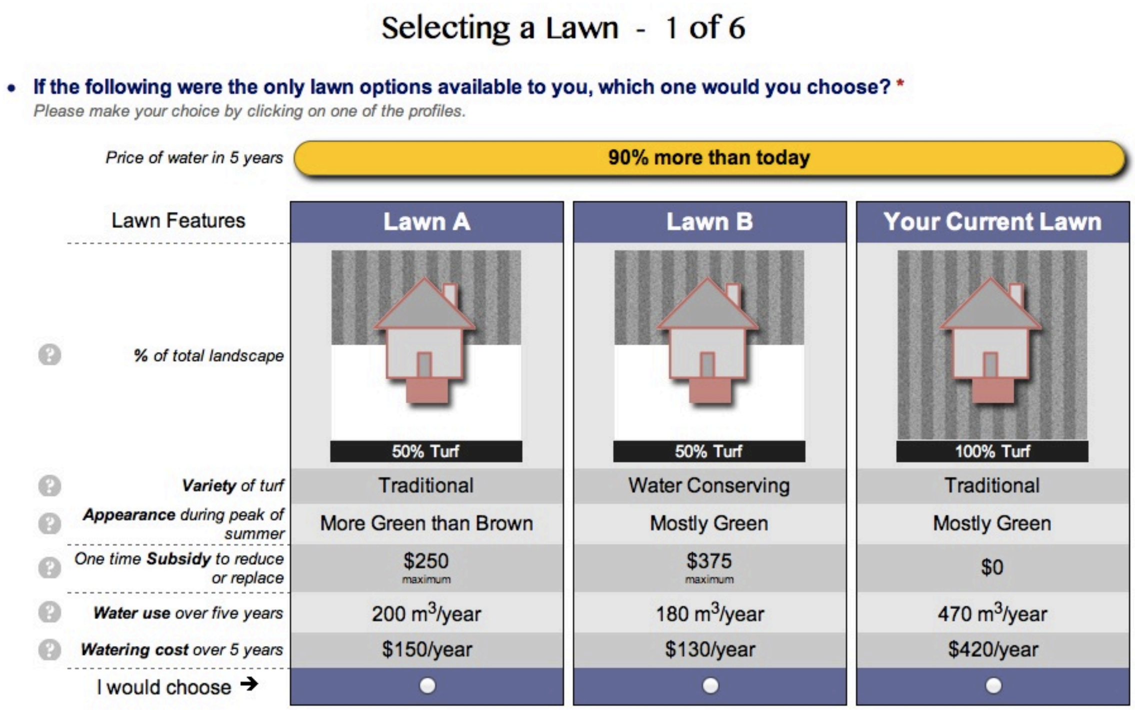


**Figure 1. Lawn choice – example screen**

In the experiment, respondents are given six sets of three lawn choices. In each of the first two choices, the attributes *% of lawn in the total landscape, variety of turf, appearance during peak of summer,* and the *amount of subsidy* are varied based on an orthogonal design of 48 possible combinations. The attributes and their range of possible levels in these choices are depicted in Table 1. The third choice remains constant and represents the respondent's current lawn as described by them earlier in the questionnaire. The *price of water in 5 years* is also varied in each of the six choice sets. Corresponding water use and water costs is calculated and presented to respondents. Respondents select the lawn they most prefer and continue to the next set until they complete six sets.

**Table 1. Possible attribute values in lawn choice experiment**

| Attribute | Levels |
|---|---|
| % of total landscape | 25%<br>50%<br>75%<br>100% |
| Variety of turf | Traditional<br>Water Conserving<br>Artificial |
| Appearance during peak of summer | Very Green<br>Mostly Green<br>More Green than Brown<br>More Brown than Green |

| Attribute | Levels |
|---|---|
| One time Subsidy to reduce or replace | $125<br>$250<br>$375<br>$500 |
| Price of water in 5 years | 30% more<br>60% more<br>90% more |

CCE – Continuous Choice Experiment

In the second choice experiment, respondents with flat water rates (i.e. South East Kelowna Irrigation District domestic water users) or without lawns present in their landscape were asked to consider the following scenario:

*Okanagan water managers **forecast the region will use 20% more water** annually by 2040. One option to meet this need is to add new water sources, such as constructing reservoirs and using more groundwater, at a cost of $100 for every household in the region. Another option is to reduce water use. Reducing water use is less costly than investing in new supplies but requires improving indoor and outdoor water efficiency.*

*Suppose every household in the Okanagan were to behave like yours, how far would you be willing to commit to change your household water use to help meet future water need? Consider the two options below (A and B) and use the sliders to indicate to what extent your household is willing to improve its water savings. There are no right or wrong answers to this question but it is important to regard it as a real-world situation, in which an investment choice is made.*

The scenario was developed based on outcomes of the 2010 Key Findings Report from the "Okanagan Water Supply & Water Demand Project Phase 2." The report highlights that given both climate and population projections and an expectation of growth in irrigable land use that annual water use by 2040 could average 19% more than today's use. The 19% estimate was rounded to 20% to simplify respondent perception. While the chosen figure is less than predicted by the 2006 Cohen and Neale report "Participatory integrated assessment of water management and climate change in the Okanagan Basin, British Columbia" suggesting that future water use could reach 446% of today's use, the research team found the lower figure suggested in the Okanagan Water Supply & Water Demand report was more applicable given future model integration plans.

The scenario was also constructed to provide insights related to future water use efficiency, such as achieving the BC Provincial goal of 33% improvements in water efficiency by 2020. Future water efficiencies directly influence future water need. Thus the scenario asks respondents to consider how much they are willing to improve their personal water efficiency to assist in meeting future water needs. As with the above DCE, respondents are given background information on the scenario and then presented with a computer screen with continuous sliders for each attribute in the design. Figure 2 illustrates the CCE slider screen used in this project.

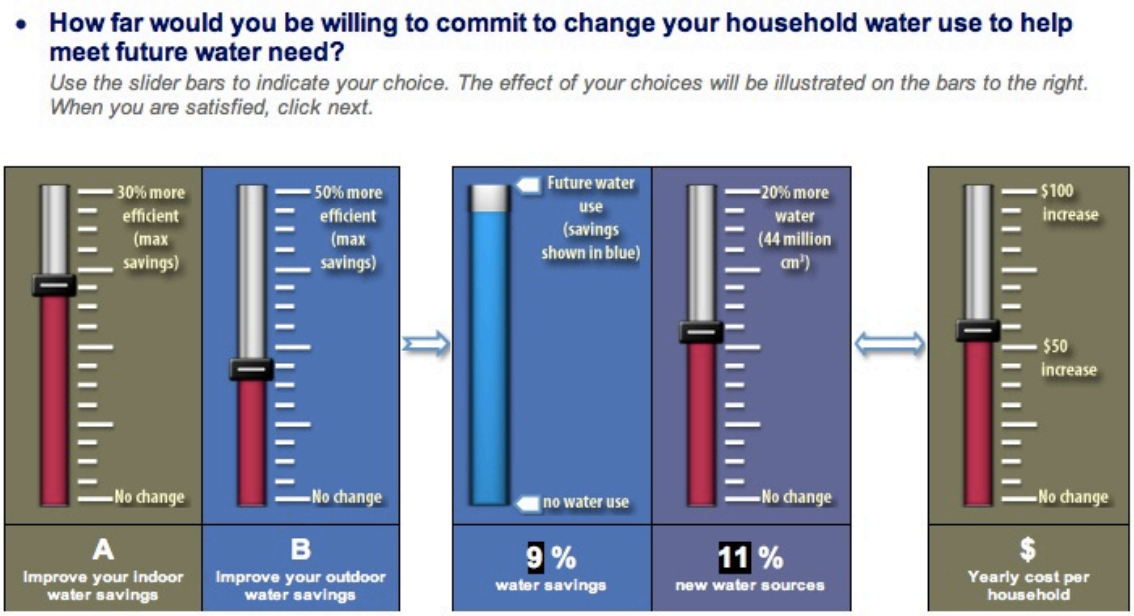


**Figure 2. CCE Water Efficiency Investment Choice Screen**

Respondents begin by considering that $100 per household is required to meet future water needs. The respondent then considers how much they are willing to commit to improving their indoor and outdoor water efficiency. On screen, respondents can indicate their choice by adjusting one or more of any of the presented slider bars. A respondent can adjust one or both of the efficiency slider bars or make their choice by sliding the *$ Yearly cost per household* or *% investment in new water sources* sliders. As sliders A & B move, the *$ Yearly cost per household* and *% investment in new water sources* sliders change according to a preprogramed cost function. Likewise, as the *% investment in new water sources* or *$ Yearly cost per household* sliders change, the A & B sliders move to the same preprogramed cost function. Total water savings are shown as an effect of adjusting any of the slider bars. When the respondent is satisfied with their choice, they click next to continue with the questionnaire. Unlike the DCE, respondents are asked to respond only one time.

4. Collect data: Once the choice experiment was designed, data collection occurred through the use of an Internet survey. The survey is described in the following section.

5. Analysis: By aggregating all responses and analyzing the data with a multinomial logit regression, it is possible to derive part worth utility functions for each attribute. These estimates will then be used to calculate the likely support for any possible attribute informing future management policies and providing behavioural metrics for later integration with the existing Okanagan Water Demand Model. Section 3 describes the outcome of this analysis.

***Internet Surveys***

To facilitate data collection, the project custom-developed two web-based water survey sites: www.waterstudy.ca to host the residential questionnaire and www.watersurvey.ca to host the farmer questionnaire. A web-based survey was selected to allow the implementation of the previously described choice experiments. The opening screen of the residential survey is shown in Figure 3.

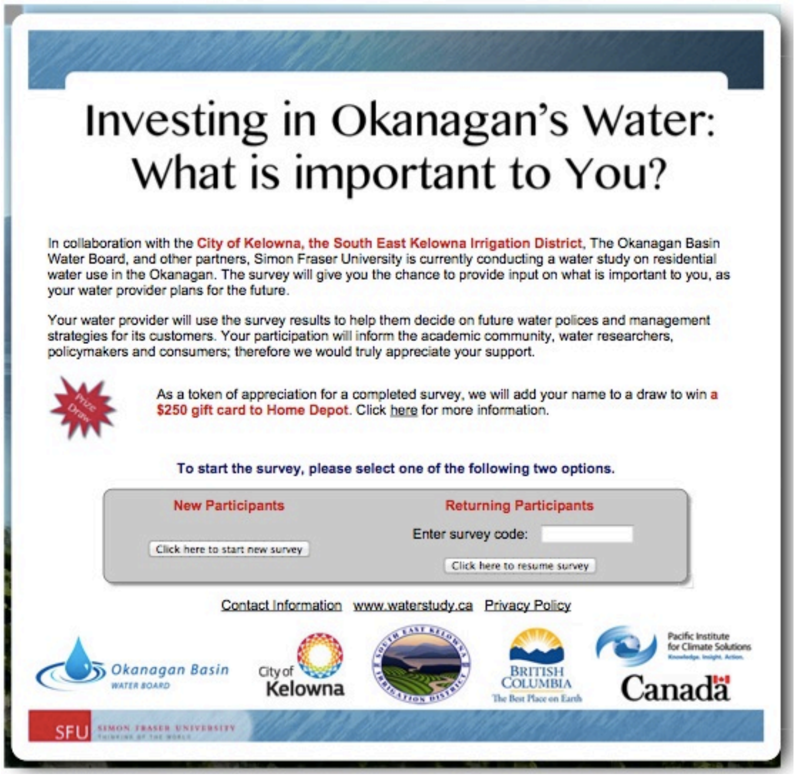


**Figure 3. Internet Survey Opening Screen**

The residential website was extensively tested by the technical steering committee, Simon Fraser University water research group members, and select Kelowna, BC area residents.

The research team with recruitment support by the City of Kelowna and the South East Kelowna Irrigation District administered the on-line survey. Water providers sent an invitation letter to 2100 randomly selected residential utility customers (1500 in the City of Kelowna and 600 in the South East Kelowna Irrigation District) with the study web address on which the survey could be found, completed, and submitted. A reminder post card and a third contact letter followed initial initiation letters. After the last contact letter, both water providers included a notice in their 2012 water newsletters inviting all utility customers to give input into the study. The date of each newsletter was closely tracked and a source question was included in the questionnaire to segment randomly selected respondents from those arriving at the study website through the newsletter or other source.

## 3. Detailed Data Results

The following section summarizes the results of the study, presented in the same order as the questionnaire. A total of 951 visits to the water study website occurred during the data collection period, representing a 45% contact response rate. Of the 951 visits, 897 respondents completed the survey for a 94% completion rate. Of those that did not complete the survey, 41 (75%) did not proceed past the survey introduction. Protest and invalid responses were identified and eliminated by reviewing the length and pattern of responses, and the completeness of each survey section. A final sample size of 841 was used in the analysis of results.

A number of statistical methods were used to analyze the data. IBM SPSS Statistics 19 was used to analyze the descriptive elements of the survey, including sample frequencies, water use behaviour and attitudes (SPSS Incorporated, 2010). The DCE was analyzed using the software package Latent Gold Choice 4.5 (Statistical Innovations Incorporated, 2010). The CCE was analyzed using the software package R 2.10.0 (The R Foundation for Statistical Computing, 2009).

## To begin, please tell us about your home - your Kelowna residence

### Who is your residence's primary water provider?

To determine who provides water for a given household, the questionnaire asked respondents to indicate if they received water from one of the sources in Table 2. The majority of respondents (66.8%) indicated that they received water from the "City of Kelowna Water Utility". The South East Kelowna Irrigation District was the second most frequent response indicated by respondents (30.7%).

**Table 2. Respondent's primary water provider.**

| Primary Water Provider | Frequency (%) (N=841) |
|---|---|
| City of Kelowna Water Utility | 66.8 |
| South East Kelowna Irrigation District | 30.7 |
| Black Mountain Irrigation District | 0.4 |
| Glenmore-Ellison Improvement District | 0.5 |
| Rutland Waterworks District | 0.1 |
| Private Well | 1.0 |
| Other | 0.5 |
| Do Not Know | 0.1 |

## How would describe your residence?

To provide context about each household's potential water consumption, respondents were asked about the residence type. In this question, respondents were asked to select one option from the following options: detached house, attached house, multi-family home, and apartment/condominium (Table 3). Most respondents indicated that their residence was a "detached house" (93.3%) while very few respondents indicated that their residence was an "attached house (townhouse, duplex, triplex, etc.)" (2.9%) or a "multi-family house" (3.1%). Less than one percent of respondents selected "apartment/condominium" (0.4%) or "mobile home" (0.4%). Invitation letters were sent to single metered utility customers.

**Table 3. Respondents' residence type.**

| Residence Type | Frequency (%) (N=836) |
|---|---|
| Detached house | 93.3 |
| Attached house (townhouse, duplex, triplex, etc.) | 2.9 |
| Multi-family house (multiple suites in a single home) | 3.1 |
| Apartment/condominium | 0.4 |
| Mobile Home | 0.4 |
| **Total** | 100 |

## How many people live in your residence?

To explore the relationships between household consumption and the amount of people living in a residence, respondents were asked to input the number of people living in their residence (Table 4). The mean response was 2.75 with a minimum response of 1 and a maximum response of 8.

**Table 4. Mean, median, mode, minimum, and maximum responses for the number of people living in a residence.**

| Mean (N=827) | Median | Mode | Minimum | Maximum |
|---|---|---|---|---|
| 2.75 | 2.00 | 2 | 1 | 8 |

## When was your current residence built?

The questionnaire also asked respondents to indicate when their house was built based on the time ranges in Table 5 and Figure 4. Less than one percent of respondents did not know when their residence was built. The frequency of time ranges indicated were relatively equally distributed between "1970 and Before" (19.1%), "1971-1980" (18.1%), "1981-1990" (17.1%), "1991-2000" (20.2%), and "2001-2012" (24.9%).

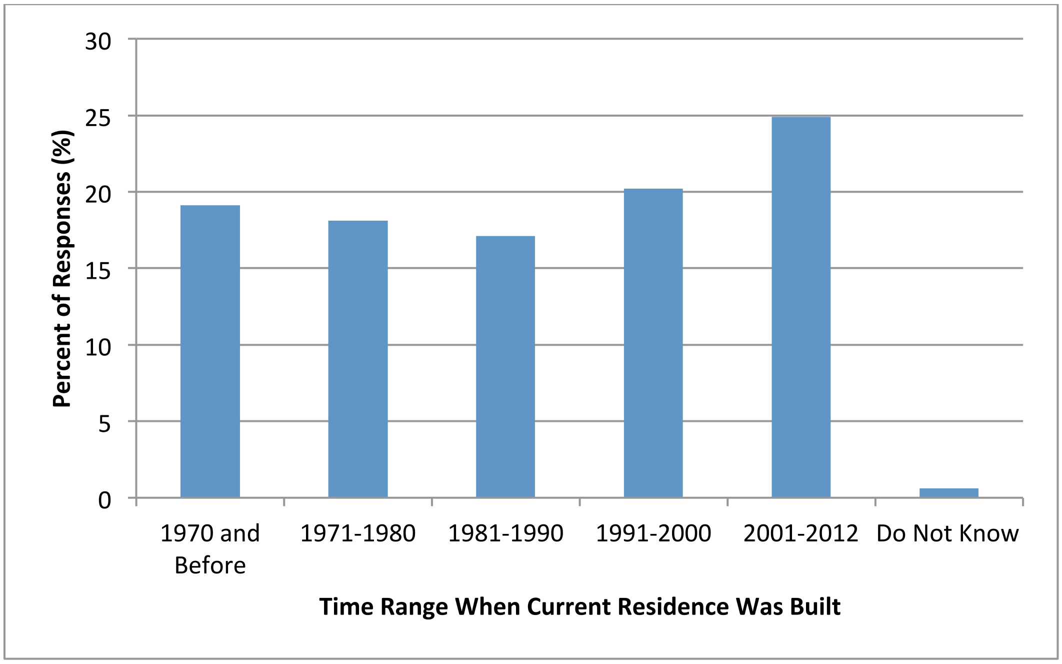


**Figure 4. Time range when current residence was built.**

**Table 5. Time range when current residence was built.**

| | **Frequency (%) (N=836)** |
|---|---|
| 1970 and Before | 19.1 |
| 1971-1980 | 18.1 |
| 1981-1990 | 17.1 |
| 1991-2000 | 20.2 |
| 2001-2012 | 24.9 |
| Do Not Know | 0.6 |
| **Total** | 100 |

## Have any of the following rooms been renovated in your residence since it was built?

Recent appliances and fixtures such as toilets, showerheads, and clothes washers tend to be more water efficient. Home renovations can indicate that newer, more water efficient fixtures have been installed in a home. Therefore, respondents were asked to indicate if their bathroom(s), kitchen, and laundry room had been renovated since it was built (Table 6; Figure 5). Fewer than half of the respondents indicated that their bathroom(s) (43.2%) and kitchen (40.4%) had been renovated while a smaller portion (23.3%) indicated that their laundry room had been renovated.

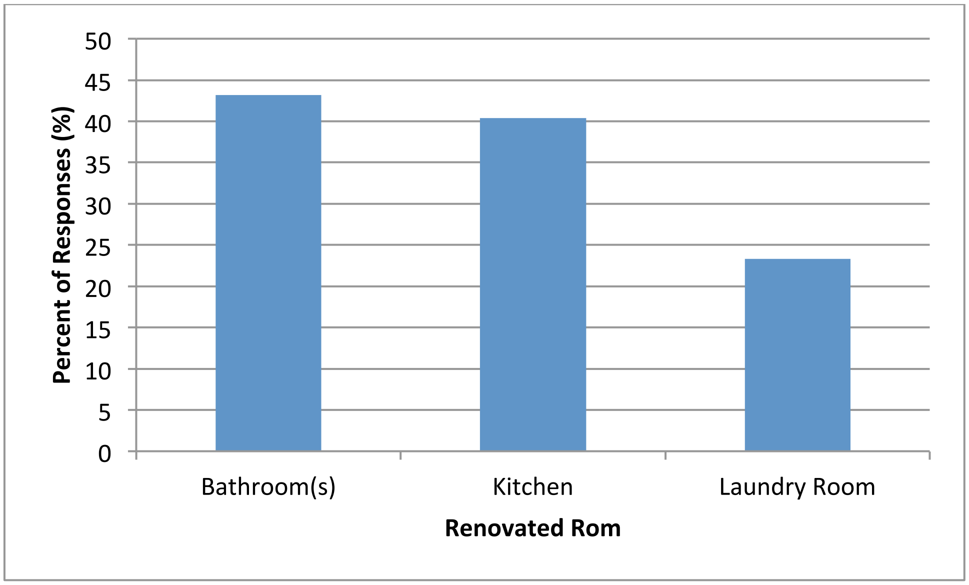


**Figure 5. Response frequencies for bathroom, kitchen, and laundry room renovations.**

**Table 6. Response frequencies for bathroom, kitchen, and laundry room renovations.**

| Room | N | Frequency (%) |
|---|---|---|
| Bathroom(s) | 363 | 43.2 |
| Kitchen | 340 | 40.4 |
| Laundry Room | 196 | 23.3 |

## Do you own or rent your residence?

Respondents were also asked if they own or rent their residence (Table 7). The vast majority of respondents answered that they own their residence (96.2%). Only 3.8% of respondents indicated that they rent their residence.

**Table 7. Frequency of respondents owning or renting their residence.**

| | Frequency (%) (N=833) |
|---|---|
| Own | 96.2 |
| Rent | 3.8 |
| **Total** | 100 |

## When did you first take up residence in the Okanagan?

The questionnaire asked respondents to indicate when they first took up residence in the Okanagan based on the time ranges in Table 8 and Figure 6. Almost one third (30.6%) of respondents took up residence between "2001-2012" and 24.6% took up residence between "1991-2000". Other responses included "1980-1990" (18.3%), "1971-1980" (11.5%), and "1970 and Before" (15.0%).

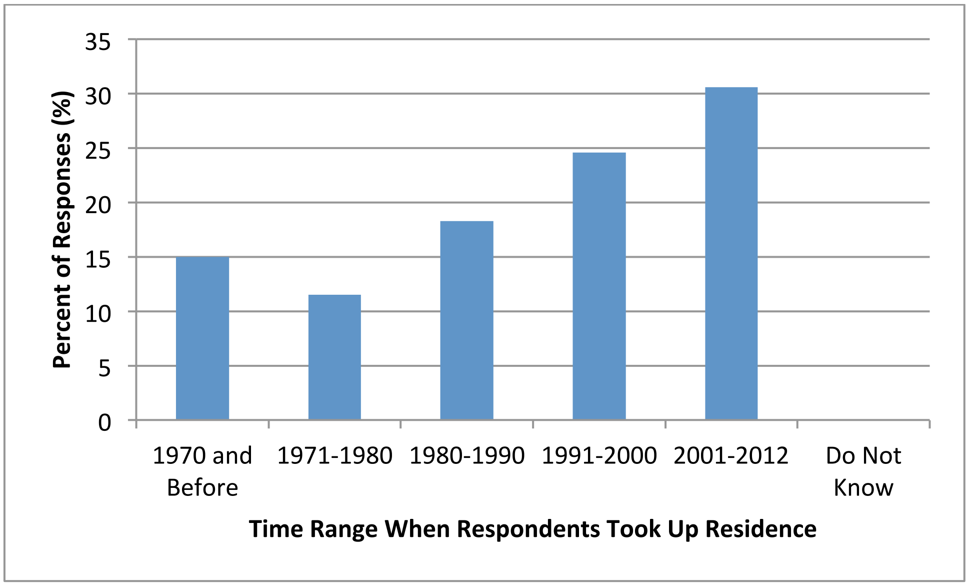


**Figure 6. Response frequencies for time ranges when respondents first took up residence in the Okanagan.**

**Table 8. Response frequencies for time ranges when respondents first took up residence in the Okanagan.**

| | **Frequency (%) (N=834)** |
|---|---|
| 1970 and Before | 15.0 |
| 1971-1980 | 11.5 |
| 1980-1990 | 18.3 |
| 1991-2000 | 24.6 |
| 2001-2012 | 30.6 |
| Do Not Know | 0.0 |
| **Total** | 100 |

### Are you a seasonal or part time resident?

To provide context about respondents' living situations, the questionnaire asked respondents if they were a seasonal or part time resident. Respondents were asked select "Yes" if they were a seasonal or part time resident or "No" if they were not a seasonal or part time resident (Table 9). Almost all respondents (95.4%) selected that they were not a seasonal or part time residents. Only 4.6% of respondents indicated that they were a seasonal or part time resident.

**Table 9. Response frequency of seasonal or part time residents.**

| | Frequency (%) (N=828) |
|---|---|
| Yes | 4.6 |
| No | 95.4 |
| **Total** | 100 |

### Do you expect to be residing in the Okanagan in 5 years?

The questionnaire also asked respondents if they expect to be residing in the Okanagan in 5 years (Table 10). The vast majority of respondents (96.3%) selected "Yes" to the question, "Do you expect to be residing in the Okanagan in 5 years?" Only 3.7% selected "No" as their response.

**Table 10. Response frequency for respondents expecting to be residing in the Okanagan in 5 years (Yes) or not expecting to be residing in the Okanagan in 5 years (No).**

| | Frequency (%) (N=837) |
|---|---|
| Yes | 96.3 |
| No | 3.7 |
| **Total** | 100 |

## Please tell us about the landscape around your home

### Approximately how large is your property?

Outdoor irrigation can significantly contribute to water use and consumption of a residence or property. To provide context about respondents' landscapes, respondents were asked to indicate their property size based on the options in Table 11 and Figure 7. Over half of respondents selected that they had "an average urban lot (between 0.15 acre and ¼ acre) (52.1%), 25.8% of respondents selected that they had "a large urban lot (between ¼ and ½ acre)," 8.8% had "a small urban lot or townhouse (~60 x 100 meters or 0.15 acre)," and 7.7% had "a larger than average urban lot or rural property (between ½ to ¾ acres)". The rest of the options were indicated by less than 5% of respondents.

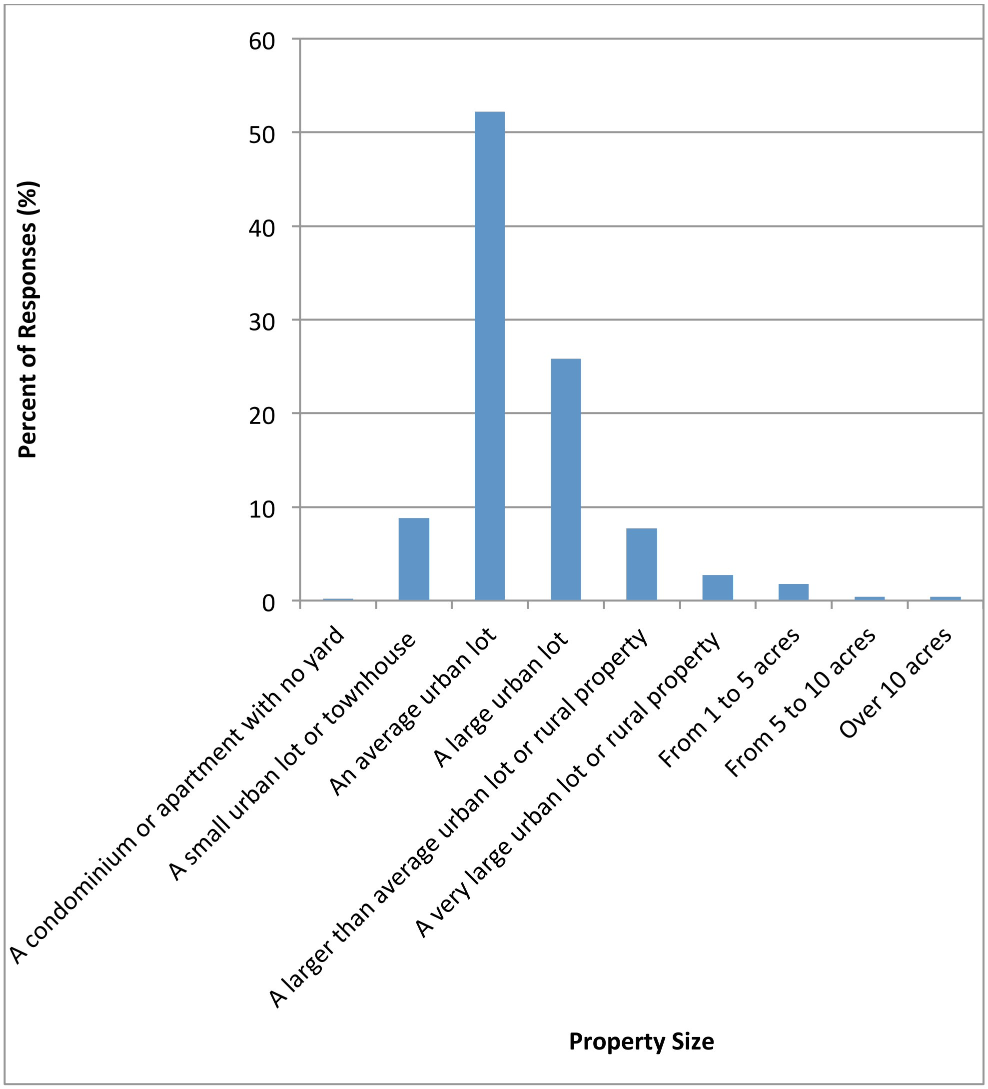


**Figure 7. Response frequencies for property sizes.**

**Table 11. Response frequencies for property sizes.**

| Property Size | Frequency (%) (N=841) |
|---|---|
| A condominium or apartment with no yard | 0.2 |
| A small urban lot or townhouse (~60 x 100 meters or 0.15 acre) | 8.8 |
| An average urban lot (between 0.15 acre and ¼ acre) | 52.2 |
| A large urban lot (between ¼  acre and ½ acre) | 25.8 |
| A larger than average urban lot or rural property (between ½ to ¾ acres) | 7.7 |
| A very large urban lot or rural property (between ¾ to 1 acres) | 2.7 |
| From 1 to 5 acres | 1.8 |
| From 5 to 10 acres | 0.4 |
| Over 10 acres | 0.4 |
| **Total** | 100 |

## How would you describe your property's landscape?

The type of vegetation on a property can increase or decrease the amount of water required to maintain a landscape. Therefore, respondents were asked to indicate if the they had any of the features in Table 12 and Figure 8 present in their landscape. Most respondents (81.5%) had a "turf or lawn", 76.2% had "traditional variety of trees, shrubs, hedges," 53.2% had "flowers and vegetable gardens," and 41.6% had "rock, gravel, and bare soil." Only 23.7% of respondents indicated that they had "water-conserving variety of trees, shrubs" and 20.8% had "native or natural landscape."

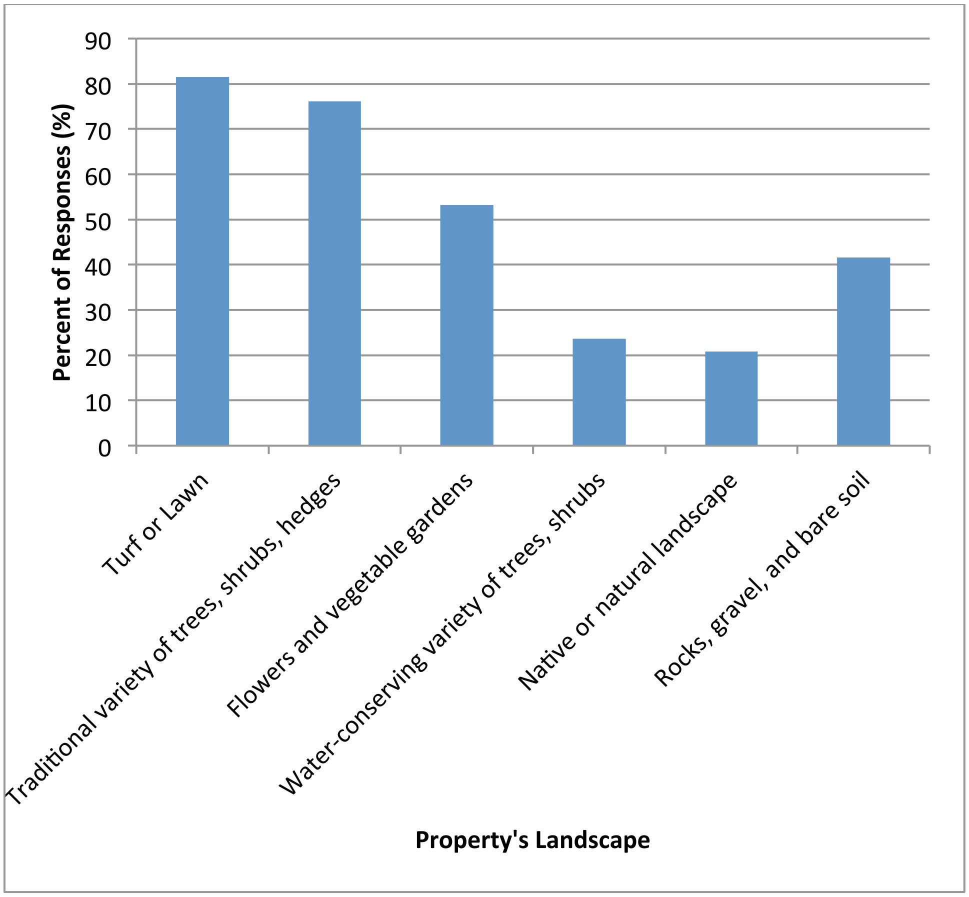


**Figure 8. Response frequencies for different landscape features.**

**Table 12. Response frequencies for different landscape features.**

| Property's Landscape | N | Frequency (%) |
|---|---|---|
| Turf or Lawn | 685 | 81.5 |
| Traditional variety of trees, shrubs, hedges | 641 | 76.2 |
| Flowers and vegetable gardens | 447 | 53.2 |
| Water-conserving variety of trees, shrubs | 199 | 23.7 |
| Native or natural landscape | 175 | 20.8 |
| Rocks, gravel, and bare soil | 350 | 41.6 |
| Other | 93 | 11.1 |

### Do you hire a professional when making alterations to your landscape?

The questionnaire asked respondents if they hire a professional when making alterations to their landscape (Table 13). Most respondents indicated "no, I make all changes myself" (55.0%) or "Yes, I have before but I also make many changes myself" (24.3%).

**Table 13. Professional and independent landscape alterations.**

| | Frequency (%) (N=834) |
|---|---|
| Yes, I routinely hire a landscape professional | 8.0 |
| Yes, I have before but I also make many changes myself | 24.3 |
| No, I make all changes myself | 55.0 |
| N/A, I have not made any changes to my landscape | 12.6 |
| **Total** | 100 |

## Please tell us how you care for your lawn

The primary purpose of this section of the questionnaire is to "warm" respondents to the attributes used in the discrete choice experiments and have respondents describe their current lawn. Answers from the following questions were used to construct the status quo situation and calculate current water use.

### Considering the yard surrounding your home, driveway, and patios, what percentage is covered by turf or lawn?

The amount of lawn present in a landscape can affect the amount of water required for a residence's outdoor irrigation. Respondents were shown diagrams of four different percentages of turf surrounding a home (from 25% turf to 100% turf) and asked to select the option that is closest to their lawn size (Table 14; Figure 9). Most respondents selected that their home was surrounded by 75% turf (32.4%), 50% turf (38.5%), and 25% turf (27.8%). Very few selected that their landscape consisted of 100% turf (1.5%).

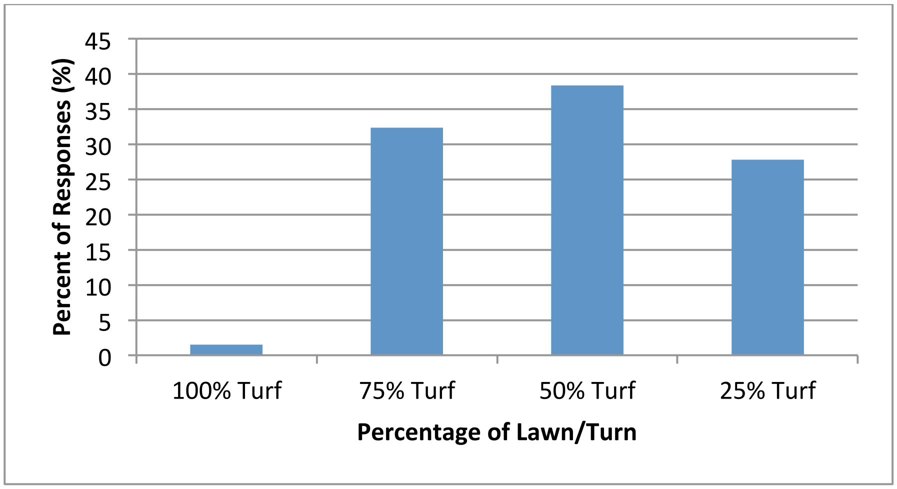


**Figure 9. Percentage of lawn/turf surrounding a home.**

**Table 14. Percentage of lawn/turf surrounding a home.**

| Turf or Lawn Percentage | Frequency (%) (N=683) |
|---|---|
| 100% Turf | 1.5 |
| 75% Turf | 32.4 |
| 50% Turf | 38.4 |
| 25% Turf | 27.8 |
| **Total** | 100 |

## What is the majority type of turf used in your lawn?

Different varieties of turf can increase or decrease the amount of water needed to maintain a lawn. To find out the distribution of lawn types in Kelowna, respondents were asked to select the majority type of turf used in their lawn from the options in Table 15. Almost all respondents (95.3%) selected "traditional (Kentucky Blue Grass, Rye grass)" as the majority type of turf used in their lawn.

**Table 15. Majority type of turf used in respondents' lawns.**

| Type of Turf | Frequency (%) (N=683) |
|---|---|
| Artificial | 0.3 |
| Traditional (Kentucky Blue Grass, Ryegrass) | 95.3 |
| Water Conserving(eco-Smart Blend, Sheep Fescue, Chewings Fescue) | 4.4 |
| **Total** | 100 |

### On average, how often is your lawn watered during the peak summer months (July, August)?

Water demand and potential water stress is highest in the peak summer months of July and August. Therefore, to learn about Kelowna residents' lawn watering habits, respondents were asked how often they water their lawn during the peak summer months (July, August). Respondents were asked to select either "almost never," "1-2 times per week," "3-4 times per week," or "5 times per week or more" (Table 16). Over half of respondents (60.5%) water their lawn relatively frequently ("3-4 times per week") while only 4.4% of respondents water their lawn "almost never."

**Table 16. Average lawn watering frequency indicated by respondents.**

| | **Frequency (%) (N=681)** |
|---|---|
| Almost never | 3.4 |
| 1-2 times per week | 31.7 |
| 3-4 times per week | 60.5 |
| 5 times per week or more | 4.4 |
| **Total** | 100 |

### On the days you water your lawn in the summer, for how many total minutes do you water?

To provide further context for residents' outdoor water consumption, the questionnaire asked respondents to provide the total minutes they water their lawn for on the days they water in the summer (Table 17; Figure 10). On average, respondents water their lawn for 48.90 minutes during summer days. Outliers were removed for z-scores of 3.0.

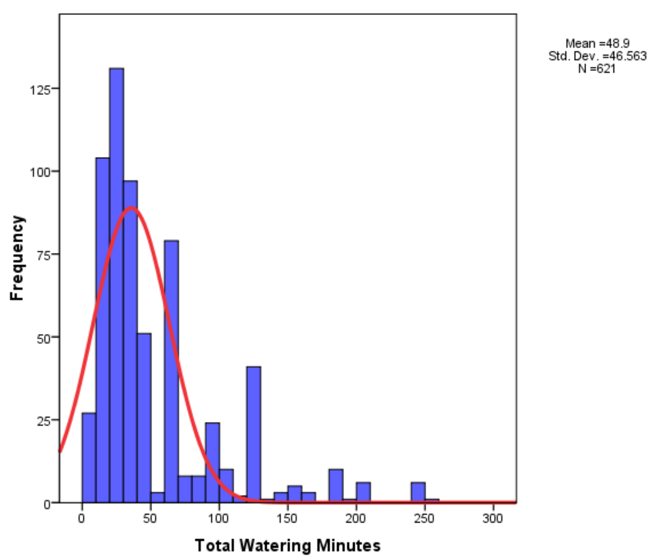


**Figure 10. Total minutes respondents water their lawn on summer days.**

**Table 17. Total minutes respondents water their lawn on summer days.**

| Mean (N=621) | Median | Mode | Minimum | Maximum |
|---|---|---|---|---|
| 48.90 | 30.00 | 20 | 0 | 250 |

## When your lawn is watered, how is it usually watered?

Different lawn watering systems are more or less water efficient. To qualify irrigation systems with future lawn choices, respondents were asked how they usually water their lawn. Respondents were asked to select one response from the options in Table 18 and Figure 11. The majority of respondents selected that they water their lawn "automatically, using an irrigation system with timer" (76.0%) followed by "manually, using a hose sprinkler" (18.0%).

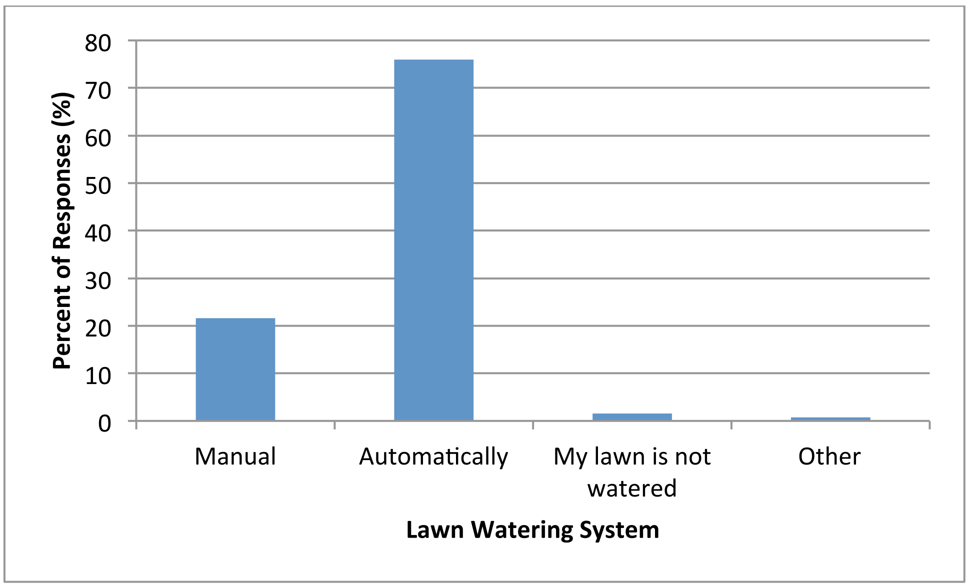


**Figure 11. Manual versus automatic lawn watering system.**

**Table 18. Lawn watering system.**

| | Frequency (%) (N=683) |
|---|---|
| Manually, using a hose sprayer | 0.7 |
| Manually, using a hose sprinkler | 18.0 |
| Manually, using an irrigation system | 2.9 |
| Automatically, using an irrigation system with timer | 76.0 |
| My lawn is not watered | 1.6 |
| Other | 0.7 |
| **Total** | 100 |

## During the peak of summer, how green or brown is your lawn?

Respondents were also asked their perception of how green or brown their lawn is during the peak of summer. Respondents selected one response in Table 19 and Figure 12 from "very green" to "more brown than green." Most respondents keep their lawn "mostly green" (41.1%) or "more green than brown" (44.8%) during the peak of summer.

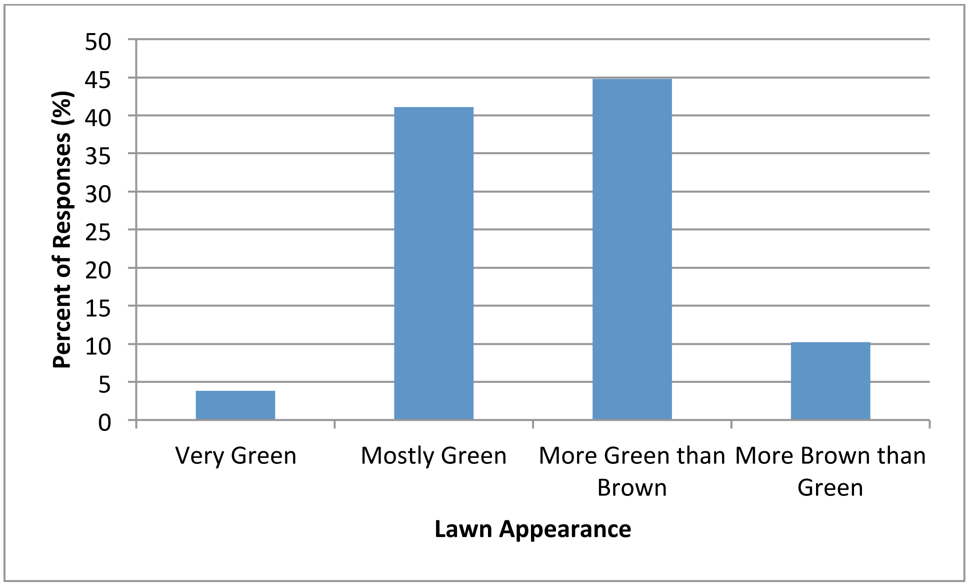


**Figure 12. Respondents' lawn appearance during the peak of summer.**

**Table 19. Respondents' lawn appearance during the peak of summer.**

| | **Frequency (%) (N=683)** |
|---|---|
| Very Green | 3.8 |
| Mostly Green | 41.1 |
| More Green than Brown | 44.8 |
| More Brown than Green | 10.2 |
| **Total** | 100.0 |

# Please tell us how you feel about your landscape

## To what extent do you agree or disagree with each of the following statements about your landscape's appearance?

Respondents were asked to what extent they agree or disagree with the statements in Table 20 and Figure 13 about their landscape's appearance. The question asked respondents to select if they "strongly agree," "agree," "neither agree nor disagree," "disagree," or "strongly disagree." Almost half of respondents "agree" with the statements "I am content with my present landscape" (45.0%), "I would like to learn more about landscape water requirements before deciding on any changes" (41.4%), and "I would like to eventually select more drought tolerant varieties of plants" (43.0%). A large portion of respondents (39.5%) indicated that they "disagree" with the statement "I do not think my neighbours would accept changes in my landscape that reduce the amount of lawn."

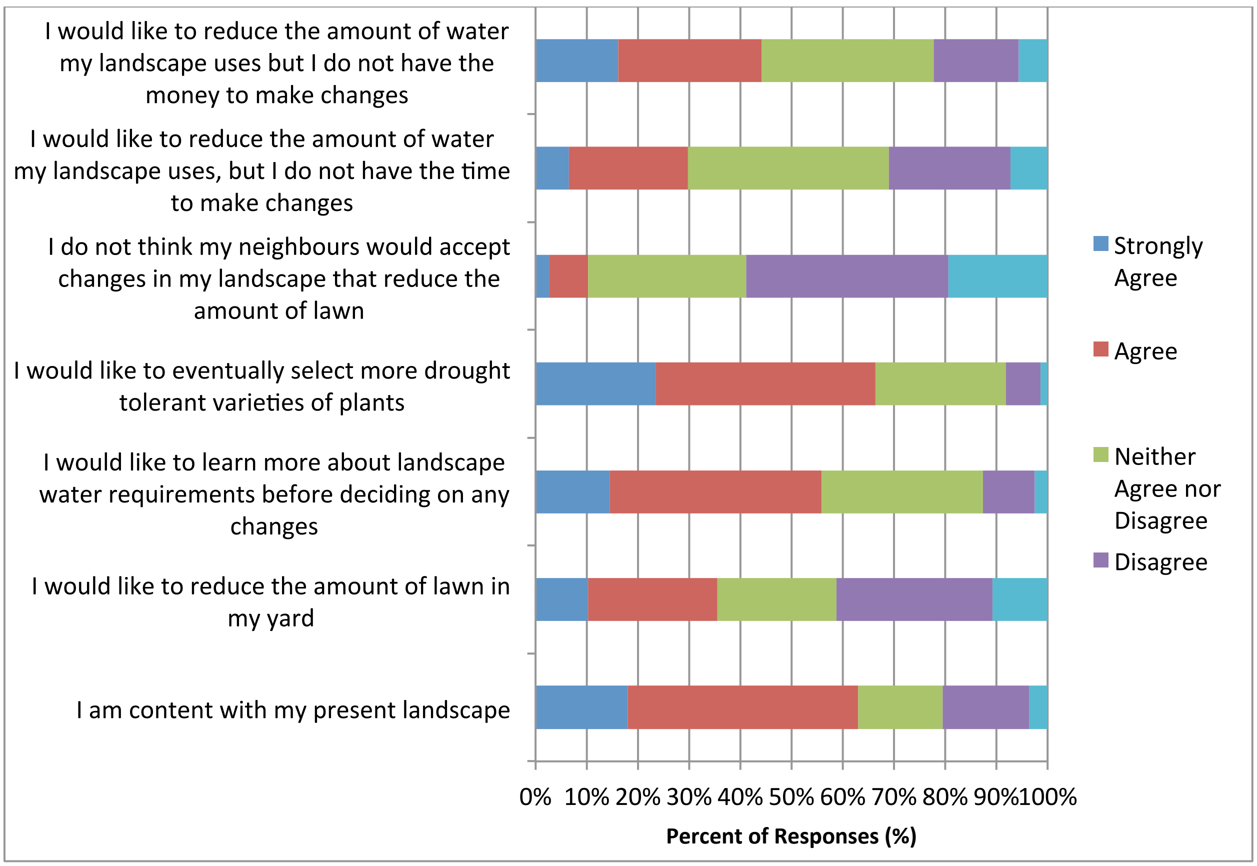


**Figure 13. Respondents' feelings about their landscape.**

**Table 20. Respondents' feelings about their landscape.**

| | Strongly Agree (%) | Agree (%) | Neither Agree nor Disagree (%) | Disagree (%) | Strongly Disagree (%) | N |
|---|---|---|---|---|---|---|
| I am content with my present landscape | 18.0 | 45.0 | 16.5 | 16.9 | 3.6 | 816 |
| I would like to reduce the amount of lawn in my yard | 10.2 | 25.3 | 23.2 | 30.4 | 10.8 | 655 |
| I would like to learn more about landscape water requirements before deciding on any changes | 14.5 | 41.4 | 31.6 | 10.1 | 2.5 | 795 |
| I would like to eventually select more drought tolerant varieties of plants | 23.5 | 43.0 | 25.4 | 6.8 | 1.4 | 800 |
| I do not think my neighbours would accept changes in my landscape that reduce the amount of lawn | 2.7 | 7.6 | 30.8 | 39.5 | 19.4 | 659 |
| I would like to reduce the amount of water my landscape uses, but I do not have the *time* to make changes | 6.5 | 23.2 | 39.3 | 23.7 | 7.3 | 798 |
| I would like to reduce the amount of water my landscape uses but I do not have the *money* to make changes | 16.2 | 28.0 | 33.6 | 16.7 | 5.6 | 804 |

## Please tell us about your household water use

### Which of the following home improvements has your household taken to reduce water use in and around your residence?

To more specifically identify if and what steps respondents' have taken to improve water efficiency in their household, respondents were asked about to select any of the options from Table 21 and Figure 14 that they have implemented to reduce water. More than half of respondents indicated that they "use a low water use dishwasher" (52.6%), "use a low water use clothes washer" (60.5%), "use low flush toilets" (56.8%), and "use low flow shower fixtures" (57.1%). The least frequent household improvement was "replaced my lawn with a water conserving variety" (2.7%).

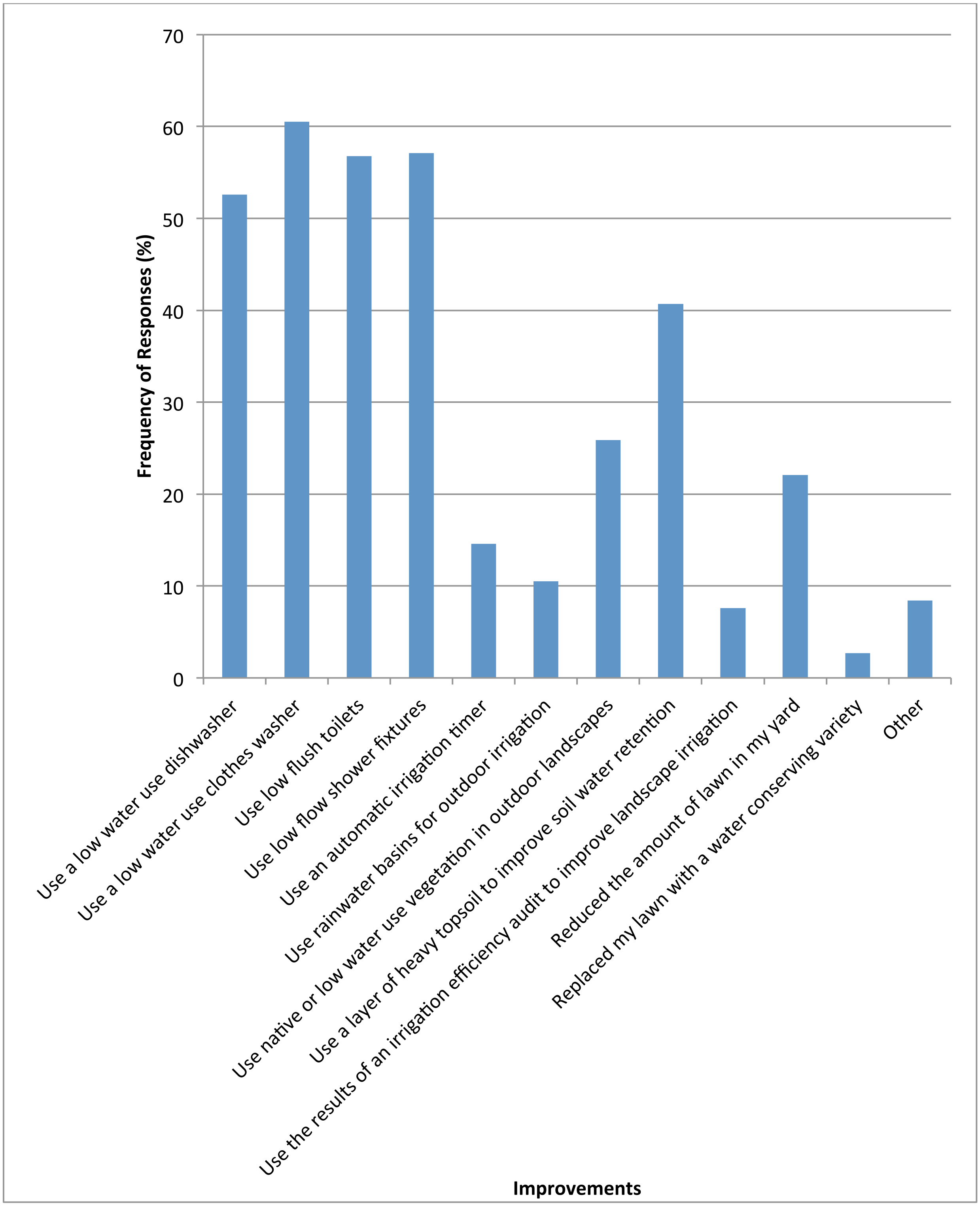


**Figure 14. Improvements to reduce water use in respondents' residences.**

**Table 21. Improvements to reduce water use in respondents' residences.**

| | N | Frequency Response (%) |
|---|---|---|
| Use a low water use dishwasher | 442 | 52.6 |
| Use a low water use clothes washer | 509 | 60.5 |
| Use low flush toilets | 478 | 56.8 |
| Use low flow shower fixtures | 480 | 57.1 |
| Use an automatic irrigation timer | 123 | 14.6 |
| Use rainwater basins for outdoor irrigation | 88 | 10.5 |
| Use native or low water use vegetation in outdoor landscapes | 218 | 25.9 |
| Use a layer of heavy topsoil to improve soil water retention | 342 | 40.7 |
| Use the results of an irrigation efficiency audit to improve landscape irrigation | 64 | 7.6 |
| Reduced the amount of lawn in my yard | 186 | 22.1 |
| Replaced my lawn with a water conserving variety | 23 | 2.7 |
| Other | 71 | 8.4 |

# You and Water Use

Determining water knowledge is one means of assessing awareness of regional water issues. The project gauged water knowledge in two different ways: first, respondents were asked to indicate their confidence in managing household water use, then respondents were asked their perceptions of how water use has changed over the last 10 years. Subsequent sections of the questionnaire included questions on what sources of information respondents trust the most to provide water knowledge and questions on respondents' perceptions of climate change and drought.

## How confident are you in your ability…

The questionnaire asked respondents about their confidence in response to the statements in Table 22 and Figure 15 about household water use. The question asked respondents to select one answer for each statement from 1 ("I cannot identify at all") to 5 ("I can identify with certainty"). For example, most respondents indicated either 3 (31.5%) or 4 (38.7%) to the statement "...to identify how to reduce indoor water use by your household."

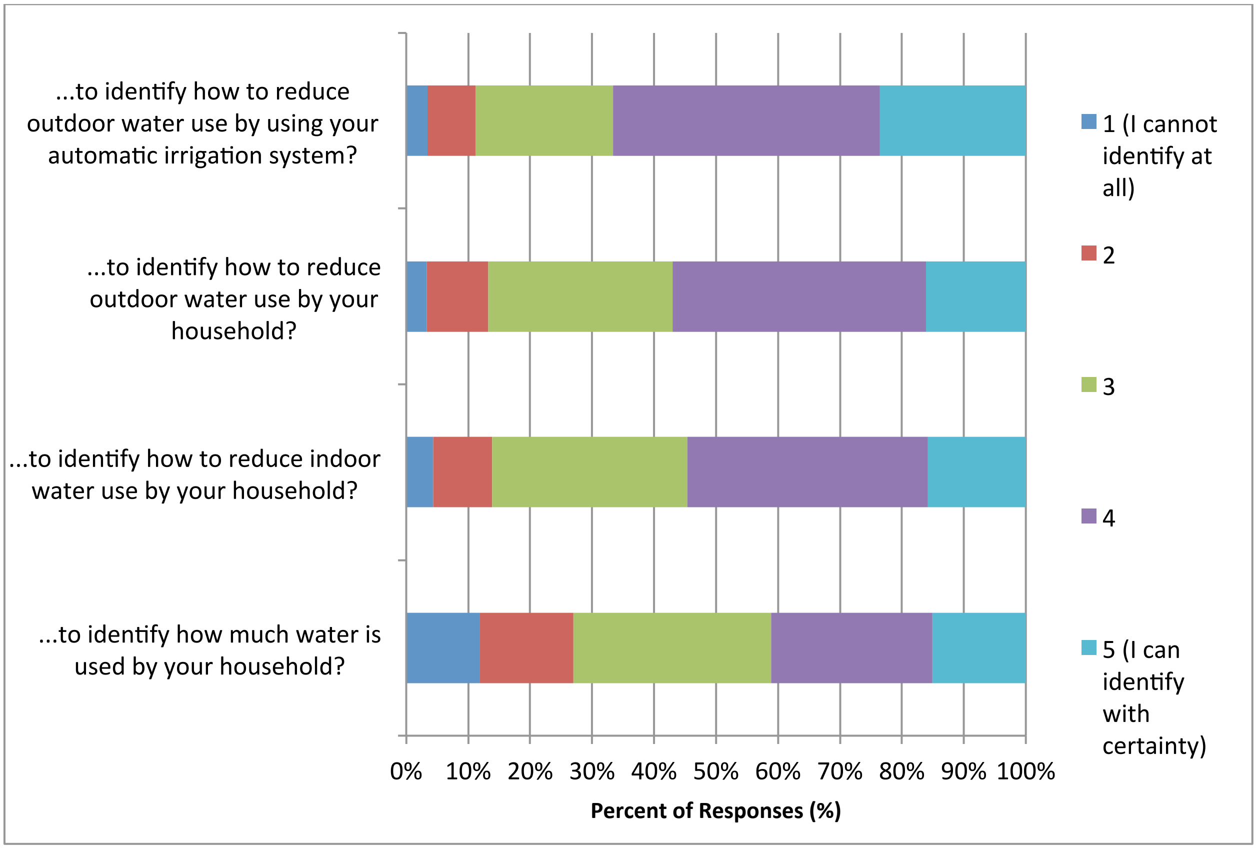


**Figure 15. Respondents confidence about household water use.**

**Table 22. Respondents confidence about household water use.**

| | 1 (I cannot identify at all) (%) | 2 (%) | 3 (%) | 4 (%) | 5 (I can identify with certainty) (%) | N (%) |
|---|---|---|---|---|---|---|
| ...to identify how much water is used by your household? | 11.9 | 15.0 | 31.9 | 25.9 | 15.1 | 826 |
| ...to identify how to reduce indoor water use by your household? | 4.3 | 9.5 | 31.5 | 38.7 | 15.8 | 821 |
| ...to identify how to reduce outdoor water use by your household? | 3.3 | 9.9 | 29.7 | 40.8 | 16.1 | 818 |
| ...to identify how to reduce outdoor water use by using your automatic irrigation system? | 3.4 | 7.8 | 22.2 | 43.1 | 23.6 | 501 |

**Which sources of information about water and water related issues in the Okanagan do you find most trustworthy?**

The questionnaire asked respondents about trusting sources of information about water and water related issues in the Okanagan that they find most trustworthy. Respondents were asked to select up to three options from the sources listed in Table 23 and Figure 16. The sources most often indicated as a trusted were "my water provider" (59.7%), "local news source" (49.5%), and "regional water board" (40.0%).

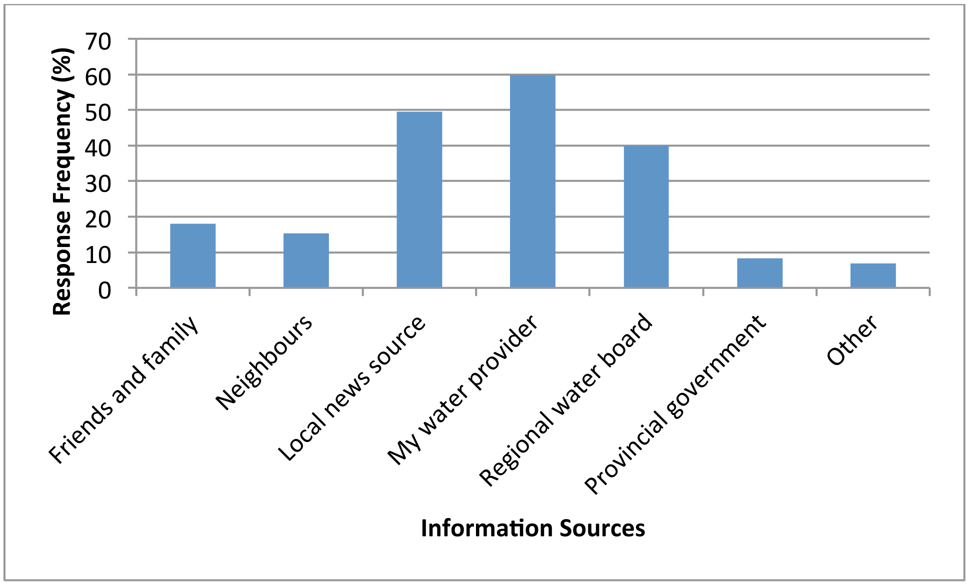


**Figure 16. Water information sources trusted by respondents.**

**Table 23. Water information sources trusted by respondents.**

| | Frequency (%) | N |
|---|---|---|
| Friends and family | 18.1 | 152 |
| Neighbours | 15.3 | 129 |
| Local news source | 49.5 | 416 |
| My water provider | 59.7 | 502 |
| Regional water board | 40.0 | 336 |
| Provincial government | 8.3 | 70 |
| Other | 6.9 | 58 |

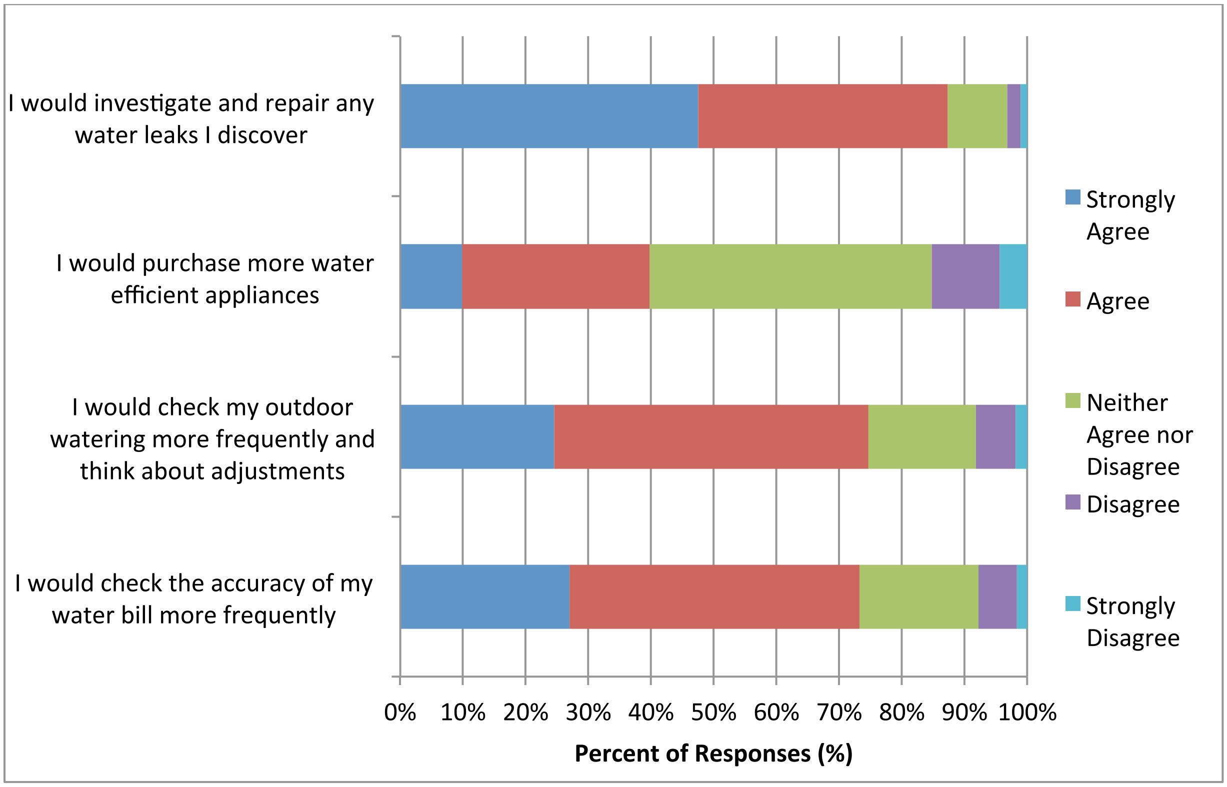


**Figure 18. Respondents' level of agreement to statements about water information displays**

**Table 24. Respondents' level of agreement to statements about water information displays**

| | Strongly Agree (%) | Agree (%) | Neither Agree nor Disagree (%) | Disagree (%) | Strongly Disagree (%) | N |
|---|---|---|---|---|---|---|
| I would check the accuracy of my water bill more frequently | 27.0 | 46.1 | 19.0 | 6.1 | 1.7 | 815 |
| I would check my outdoor watering more frequently and think about adjustments | 24.6 | 50.1 | 17.2 | 6.3 | 1.9 | 810 |
| I would purchase more water efficient appliances | 9.9 | 29.9 | 45.0 | 10.8 | 4.4 | 798 |
| I would investigate and repair any water leaks I discover | 47.5 | 39.8 | 9.5 | 2.1 | 1.1 | 812 |

To test whether respondents' behaviour would differ with information present online or in the home alternating respondents were asked to consider information on the Internet or on an in-home display. Table 25 shows the different between display modes. An independent samples t-test revealed no significant differences for alpha a priori of 0.05 ($p<0.05$) between respondents who were asked if they were given this information via an online display of in-home display.

**Table 25. Response frequency comparison for online versus in-home display.**

| | Display Type | Strongly Agree (%) | Agree (%) | Neither Agree nor Disagree (%) | Disagree (%) | Strongly Disagree (%) | N |
|---|---|---|---|---|---|---|---|
| I would check the accuracy of my water bill more frequently | Online | 29.0 | 45.9 | 17.4 | 6.4 | 1.2 | 407 |
| | In-home Display | 24.9 | 46.6 | 20.4 | 5.9 | 2.2 | 406 |
| I would check my outdoor watering more frequently and think about adjustments | Online | 24.4 | 49.1 | 18.0 | 6.9 | 1.5 | 405 |
| | In-home Display | 24.6 | 51.1 | 16.4 | 5.7 | 2.2 | 403 |
| I would purchase more water efficient appliances | Online | 10.6 | 28.3 | 45.7 | 11.4 | 4.0 | 396 |
| | In-home Display | 9.3 | 31.3 | 44.5 | 10.3 | 4.8 | 400 |
| I would investigate and repair any water leaks I discover | Online | 49.8 | 38.9 | 8.4 | 2.0 | 1.0 | 404 |
| | In-home Display | 45.3 | 40.6 | 10.6 | 2.2 | 1.2 | 406 |

# Choose your preferred landscape (DCE)

Haider & Rasid (2002) describes how data from a DCE is derived from discrete choice theory that postulates choices can be modeled as a function of the attributes of the alternatives given. It is assumed that an individual selects the alternative (*i*) that has the greatest overall utility and that each attribute contributes to a part of the compound utility of the alternative. This type of selection of compound part-worth utilities ($a_i = a_i^1, \ldots, a_i^n$) implies that the overall utility ($U_i$) of the alternative chosen is greater than the utility of the other alternatives. The total utility of the alternative ($U_i$) can be represented with a deterministic component ($V_{(a_i)}$) and stochastic component ($\mathcal{E}_i$):

$$U_i = V_{(a_i)} + \mathcal{E}_i$$

Haider and Rasid (2002) further discuss how the probability that an alternative ($i$) would be chosen from the set of alternatives ($C$) can then be represented as:

$$prob\{i\ chosen\} = \ prob\{U_i > U_j; \forall j \in C\} = {e^{V_i}}\Big/{\sum e^{V_j}}$$

Where the probability of choosing *(i)* equals the exponent of all the attributes of alternative *(i)* over the sum of the exponent of all attributes of all alternatives, *(j)*. An estimate of ($V_i$) can be derived using multinomial logit regression to provide an estimate of the part-worth utility values for each alternative (such as those given in Table 1). These part-worth utility values indicate the relative significance of each attribute and an estimate of the likelihood an alternative would be chosen.

Using Latent Gold Choice, the DCE was analyzed for latent class groups and an estimate of coefficients of all attributes. Table 26 presents the results of the DCE analysis by listing part-worth utility estimates. These estimates will be used to create a decision support system (DSS) and form the basis for developing a behavioural model for later integration with the Okanagan Water Demand Model.

The DCE was designed as an alternative specific experiment that presents three alternatives (Lawn choice A, Lawn choice B and the respondents' Current Lawn - see Figure 1) in each choice set. Therefore the intercepts shown in Table 26 represent the preferences for these options relative to each other. The resulting intercepts indicate that respondents prefer their current lawn to the two alternatives. Usually a strong preference for the status quo would indicate that respondents do not prefer the combination of attributes presented, however since option 3 also includes the same attribute levels as those in Lawn choice A and B, it is still possible to analyze each attribute for its part-worth utility.

Figure 19 illustrates graphically each attribute's part-worth utility. Results indicate a decreasing utility for smaller lawn sizes. Although residents may be considering the amount of water used in their choices as artificial and water conserving varieties of turf show positive utilities. Lawn replacement subsidies do not appear to be significant and "more brown than green" lawns, as expected, have a negative utility estimate. What is unique is that very green lawns are also shown with a negative utility. This could further indicate a consideration of water use in selecting landscape features and or a dislike for extreme lawn conditions.

**Table 26. Results of the DCE Analysis: MNL Regression estimates**

| Attribute and Attribute Level | | Estimate | S.E. | z-value |
|---|---|---|---|---|
| *Intercepts* | | | | |
| Lawn A | | -2.166 | 0.1732 | -12.5047 |
| Lawn B | | -1.9911 | 0.1726 | -11.5374 |
| Current Lawn | | **4.1571** | 0.3396 | 12.2417 |
| *Lawn Size* | | | | |
| 100% Turf | | 0.9942 | 0.2441 | 4.0737 |
| 75% Turf | | 0.889 | 0.1191 | 7.4619 |
| 50% Turf | | 0.0577 | 0.0901 | 0.6405 |
| 25%Turf | | **-1.941** | 0.2593 | -7.4842 |
| *Lawn Variety* | | | | |
| Artificial | | 0.0346 | 0.092 | 0.3757 |
| Traditional | | -0.3554 | 0.0589 | -6.0365 |
| Water Conserving | | 0.3208 | 0.0656 | 4.8888 |
| *Lawn Appearance* | | | | |
| Very Green | | **-0.2936** | 0.0751 | -3.9078 |
| Mostly Green | | 0.2398 | 0.0692 | 3.4645 |
| More Green than Brown | | 0.2452 | 0.0649 | 3.7769 |
| More Brown than Green | | -0.1915 | 0.0703 | -2.7252 |
| *Subsidy Level* | | | | |
| | $125.00 | -0.0176 | 0.0641 | -0.2745 |
| | $250.00 | -0.1392 | 0.0679 | -2.0504 |
| | $375.00 | 0.2813 | 0.0646 | 4.3574 |
| | $500.00 | -0.1246 | 0.0665 | -1.872 |

$Rho^2$=0.2241. All estimates have p-values <.001. z-values < -1.96 or > 1.96 indicate the estimate is statistically significantly. Analysis accounts for interactions between a respondent's current lawn size and the lawn sizes presented in Lawn A and Lawn B choices.

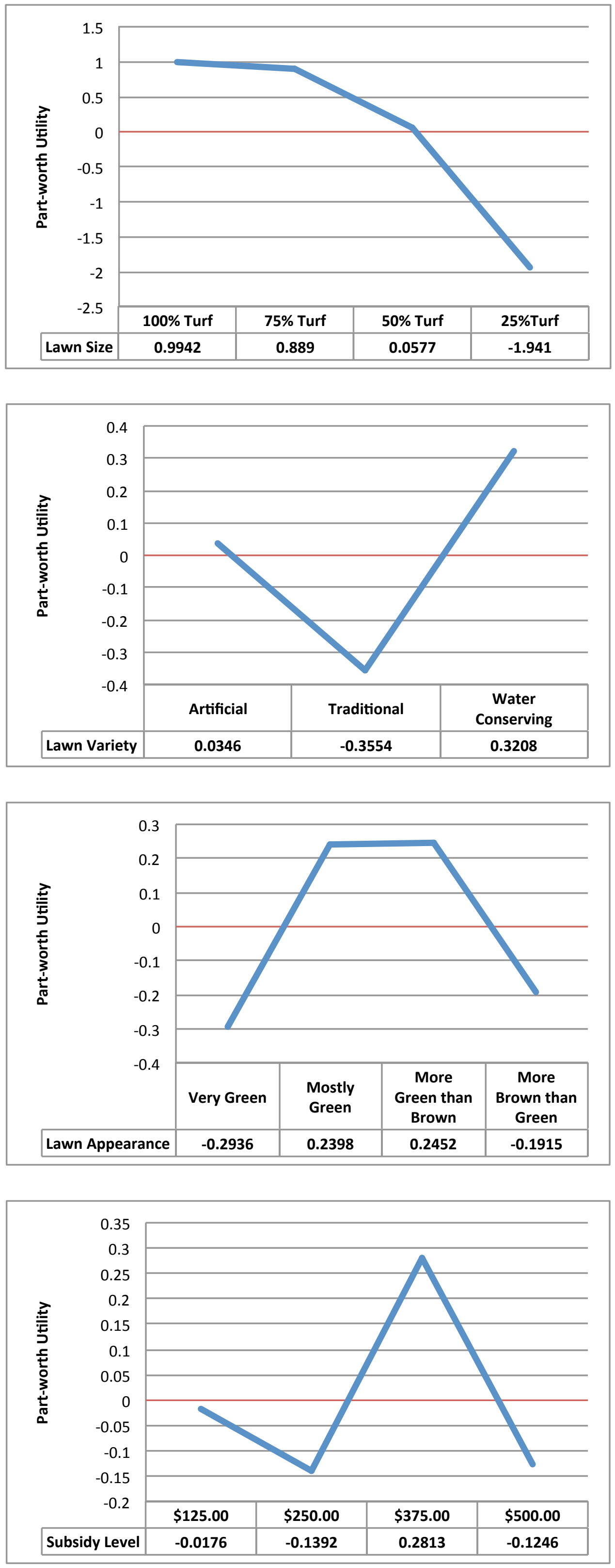


**Figure 19. Part-worth utilities by lawn choice attribute**

# Investment Choice (CCE)

## How far would you be willing to commit to change your household water use to help meet future water need?

In the previously described DCE, respondents were asked to make trade-offs between presented choices with defined attribute levels. By contrast, a CCE asks respondents to indicate their preferred attribute levels by adjusting the attribute level in a given range of options. In doing so, it is possible to generate unique attribute levels for each respondent (Ready et al., 2006). Given unique attribute levels for all respondents, individual utility estimates can be derived using regression analysis. Because the upper and lower bounds are constrained in the study, the data generated is censored. A Tobit regression model (see Table 27) was employed to calculate willingness to pay estimates and population averages.

Table 28 describes the population averages for each investment option and Table 27 describes the marginal willingness to pay to avoid investing in a % improvement in water efficiency.

**Table 27. CCE Tobit regression model**

| Tobit Factors | Value *WTP | Std. Error | t-value |
|---|---|---|---|
| **Indoor** | | | |
| (Intercept):1 | 90.968 | 2.418763 | 37.609 |
| (Intercept):2 | 2.895 | 0.046351 | 62.458 |
| Indoor water efficiency | -2.9806* | 0.133169 | -22.382 |
| **Outdoor** | | | |
| (Intercept):1 | 99.7107 | 0.728819 | 136.811 |
| (Intercept):2 | 1.6167 | 0.047416 | 34.096 |
| Outdoor water efficiency | -1.9613* | 0.022737 | -86.261 |

**Table 28. CCE Population averages**

| Investment Option | Minimum (N=244) | Median | Mean | Max | s.d. |
|---|---|---|---|---|---|
| Improve Indoor water efficiency (%) | 0 | 15.0 | 16.2 | 30.0 | 9.35 |
| Improve Outdoor water efficiency (%) | 0 | 26.5 | 28.7 | 50.0 | 15.06 |
| Invest in new Water (million $cm^3$) | 0 | 22 | 19.2 | 44 | 12.72 |
| Yearly cost per household ($) | 0 | 50 | 43.69 | 100 | 28.82 |
| Overall water use reduction (%) | 0 | 10.0 | **11.26** | 20.0 | 5.76 |
| Overall new water supply investment (%) | 0 | 10.0 | **8.74** | 20.0 | 5.76 |

# Your Opinion on Water Use in the Okanagan – 1

## In your opinion, how have each of the following water uses changed in the Okanagan region over the last 10 years?

To learn about respondents` perceptions of water use by different sectors in the Okanagan and assess water knowledge, respondents were asked to indicated whether they thought water use has "increased," "not changed," "decreased," or "do not know" for the sectors in Table 29 and Figure 20. About half of respondents indicated that they believe "water used by residents" (55.5%), "water used by business" (41.3%), and "water used by golf courses" (45.5%) have increased in the Okanagan over the last 10 years.

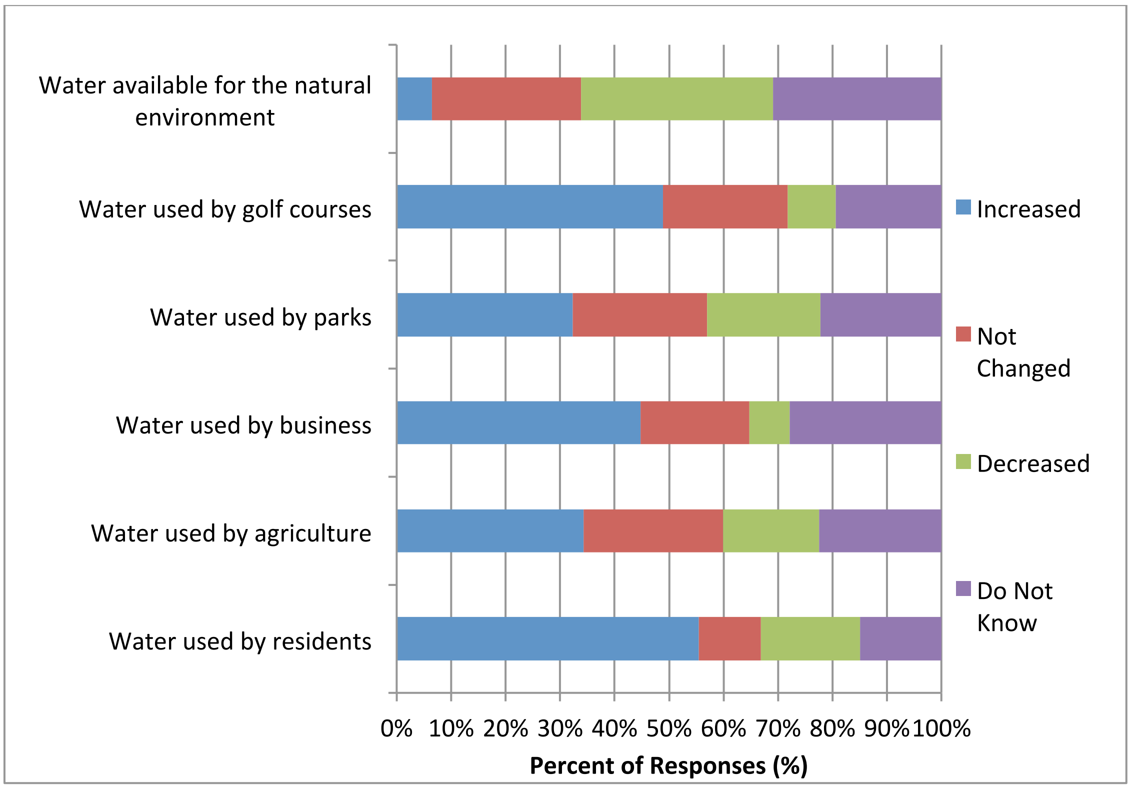


**Figure 20. Respondents perceptions of changing water use.**

**Table 29. Respondents perceptions of changing water use.**

| | Increased (%) | Not Changed (%) | Decreased (%) | Do Not Know (%) | N |
|---|---|---|---|---|---|
| Water used by residents | 55.5 | 11.4 | 18.1 | 15.0 | 789 |
| Water used by agriculture | 34.3 | 25.6 | 17.6 | 22.5 | 788 |
| Water used by business | 44.8 | 20.0 | 7.4 | 27.9 | 775 |
| Water used by parks | 32.3 | 24.7 | 20.8 | 22.2 | 784 |
| Water used by golf courses | 48.9 | 23.0 | 8.8 | 19.4 | 784 |
| Water available for the natural environment | 6.5 | 27.3 | 35.3 | 30.9 | 780 |

## To what extent do you personally agree or disagree with each of the following statements about water use in the Okanagan Basin?

Respondents were asked to select one response from "strongly agree" to "strongly disagree" for the five statements in Table 30 and Figure 21. A large portion of respondents (19.6% "strongly agree" and 59.8% "agree") believe that "water conservation programs should include options for changing water users' behaviour." Most respondents "agree" (59.9%) or "strongly agree" (17.5%) that "water conservation is an issue I am personally concerned about." This could indicate some bias in response occurred because the majority of respondents who took the survey were personally concerned with water issues.

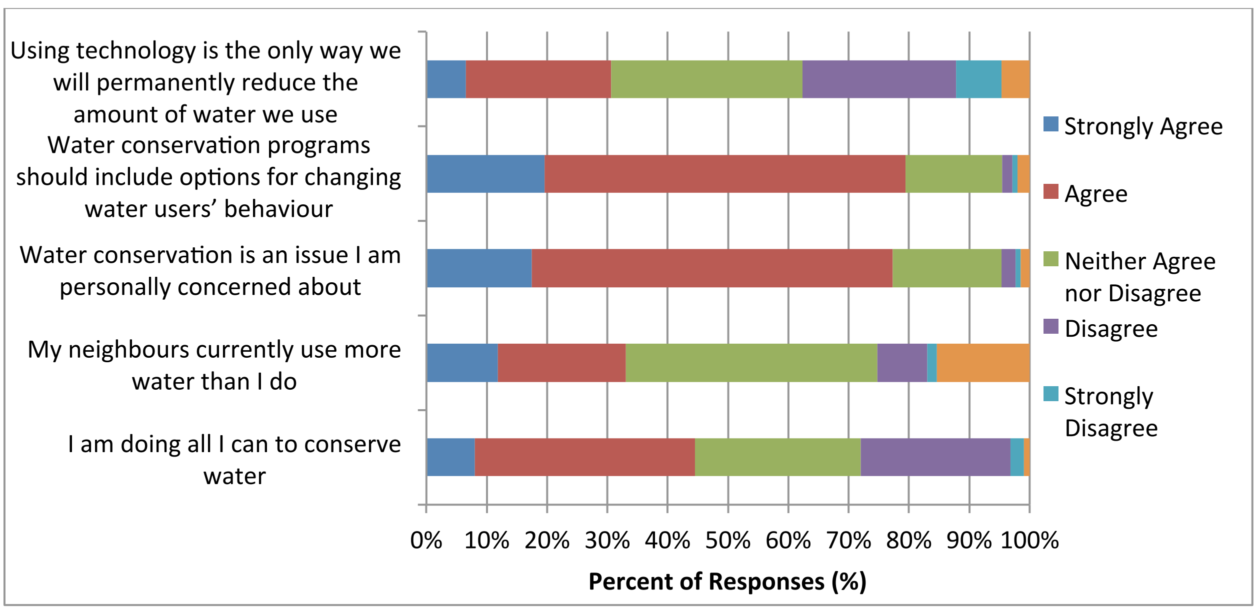


**Figure 21. Respondents attitudes towards water use in the Okanagan Basin.**

**Table 30. Respondents attitudes towards water use in the Okanagan Basin.**

| | Strongly Agree (%) | Agree (%) | Neither Agree nor Disagree (%) | Disagree (%) | Strongly Disagree (%) | No Opinion (%) | N |
|---|---|---|---|---|---|---|---|
| I am doing all I can to conserve water | 8.0 | 36.6 | 27.5 | 24.8 | 2.3 | 0.9 | 790 |
| My neighbours currently use more water than I do | 11.8 | 21.2 | 41.7 | 8.3 | 1.5 | 15.4 | 784 |
| Water conservation is an issue I am personally concerned about | 17.5 | 59.9 | 18.0 | 2.4 | 0.8 | 1.5 | 785 |
| Water conservation programs should include options for changing water users' behaviour | 19.6 | 59.8 | 16.0 | 1.7 | 0.9 | 2.0 | 787 |
| Using technology is the only way we will permanently reduce the amount of water we use | 6.5 | 24.1 | 31.7 | 25.5 | 7.5 | 4.7 | 788 |

### To what extent do you personally agree or disagree with each of the following statements about managing Okanagan's water resources?

A key covariate is a measure of individuals' perceptions of and attitudes towards water management in the Okanagan Basin. To reveal these perceptions and attitudes, respondents were asked about their level of agreement with statements about managing the Okanagan's water resources (Table 31; Figure 22). Over half of respondents selected "disagree" (39.3%) or "strongly disagree" (13.4%) for the statement "water restrictions should be voluntary rather than mandated by the government." These results indicate that respondents believe that water restrictions should not be voluntary. Most respondents selected "agree" (62.3%) or "strongly agree" (25.4%) for the statement "regional land use and water planning is needed to manage water scarcity." Also, the majority of respondents believe that "growth of cities should be limited to manage water scarcity" and "public money should be used to develop or acquire new water resources." These results might indicate that respondents believe that cities should be planned and managed to prevent water scarcity by both limiting growth and using public funds to expand water resources.

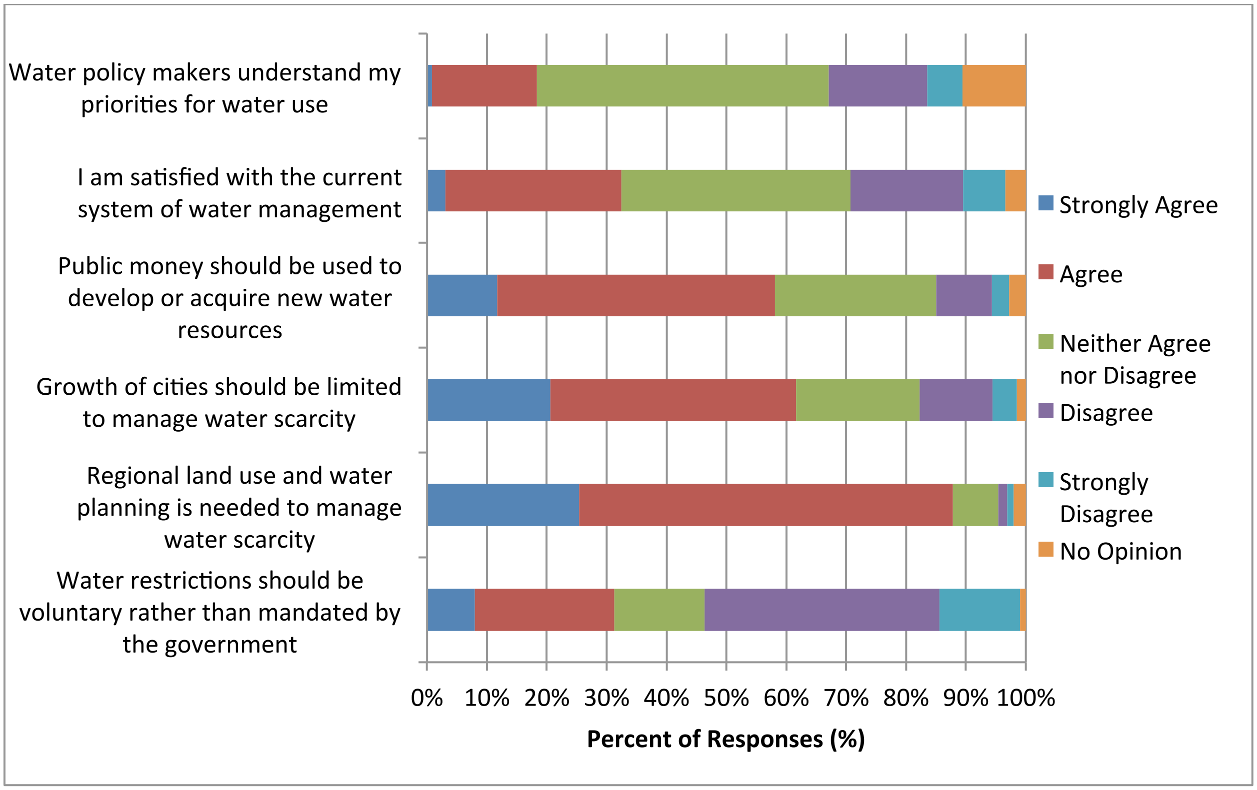


**Figure 22. Respondents level of agreement with statements about managing the Okanagan's water resources.**

**Table 31. Respondents level of agreement with statements about managing the Okanagan's water resources.**

| | Strongly Agree (%) | Agree (%) | Neither Agree nor Disagree (%) | Disagree (%) | Strongly Disagree (%) | No Opinion (%) | N |
|---|---|---|---|---|---|---|---|
| Water restrictions should be voluntary rather than mandated by the government | 8.0 | 23.3 | 15.0 | 39.3 | 13.4 | 1.0 | 786 |
| Regional land use and water planning is needed to manage water scarcity | 25.4 | 62.3 | 7.6 | 1.5 | 1.1 | 2.0 | 785 |
| Growth of cities should be limited to manage water scarcity | 20.6 | 41.1 | 20.6 | 12.2 | 4.1 | 1.5 | 788 |
| Public money should be used to develop or acquire new water resources | 11.7 | 46.3 | 26.9 | 9.3 | 2.9 | 2.8 | 784 |
| I am satisfied with the current system of water management | 3.1 | 29.3 | 38.3 | 18.8 | 7.1 | 3.4 | 786 |
| Water policy makers understand my priorities for water use | 0.8 | 17.6 | 48.7 | 16.5 | 5.9 | 10.6 | 784 |

# Your Opinion on Water Use in the Okanagan - 2

## Which of the following statements most accurately reflects your opinion about climate change in the Okanagan?

To identify respondents' opinions about climate change in the region, the questionnaire asked respondents to select a response about climate change from Table 32 that most accurately reflects their opinion. From these results, the majority of respondents (64.9%) believe that climate change is occurring presently.

**Table 32. Respondents' opinions about climate change in the Okanagan.**

| | **Frequency (%) (N=777)** |
|---|---|
| Yes, climate change will happen, but its indication will only become apparent later. | 6.6 |
| Yes, climate change is happening; first indications are apparent already. | 64.9 |
| The statements about climate change are too uncertain. It is too early to have an opinion about it. | 23.2 |
| No, I do not believe in climate change. | 3.2 |
| Other | 2.2 |
| **Total** | 100 |

## Have you noticed any changes to the following climate events in the Okanagan?

To provide context to respondents' opinions about and perceptions of climate change in the Okanagan, respondents were asked if they have noticed any changes in climate events listed in Table 33 and Figure 23. Respondents selected one response for each statement from "increased," "not changed," decreased," and "do not know." More than half of respondents (51.5%) believe that "the severity of winters has decreased."

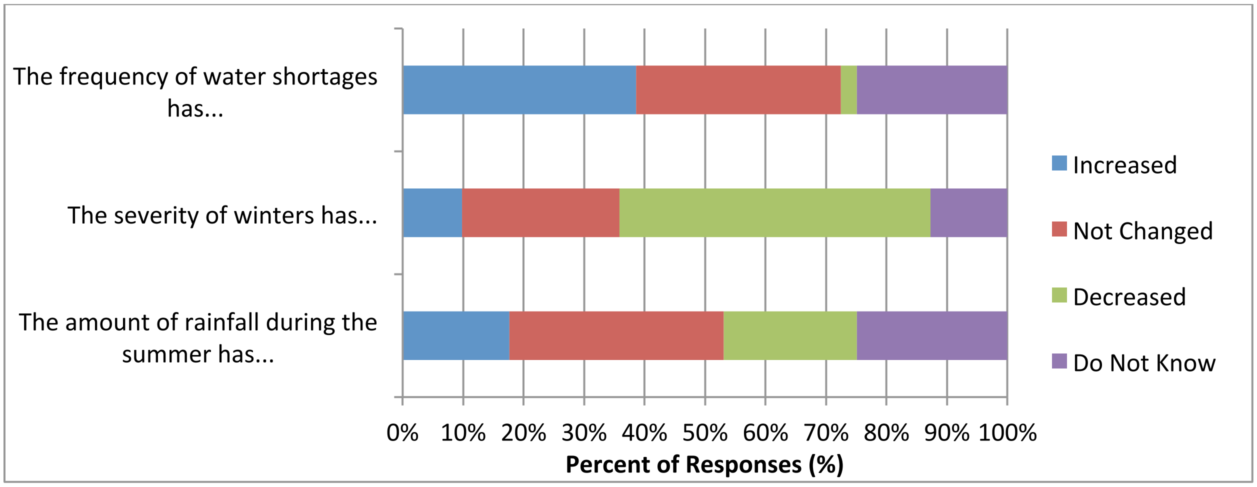


**Figure 23. Respondents' opinions about changing climate events in the Okanagan**

**Table 33. Respondents' opinions about changing climate events in the Okanagan**

| | Increased (%) | Not Changed (%) | Decreased (%) | Do Not Know (%) | N |
|---|---|---|---|---|---|
| The amount of rainfall during the summer has... | 17.6 | 35.5 | 22.0 | 24.9 | 786 |
| The severity of winters has... | 9.8 | 26.0 | 51.5 | 12.7 | 786 |
| The frequency of water shortages has... | 38.6 | 33.8 | 2.7 | 24.9 | 784 |

**During short-term water scarcity events, how acceptable would each of the following water management programs be to you?**

In times of water scarcity, different water management programs minimize water stress. Respondents were asked to select how acceptable each of the water management programs in Table 34 and Figure 24 would be to them. The majority of respondents find "restricting the amount of water that can be used on private lawns and landscapes" and "restricting the amount of water than can be used on public landscapes" to be acceptable (either 4 or 5=very acceptable). Conversely, respondents indicated that "temporarily paying farmers to reduce production," "allowing local lakes and reservoirs to drain," and "reducing the amount of water available for wildlife and fish habitat" to be unacceptable (either 2 or 1=very unacceptable).

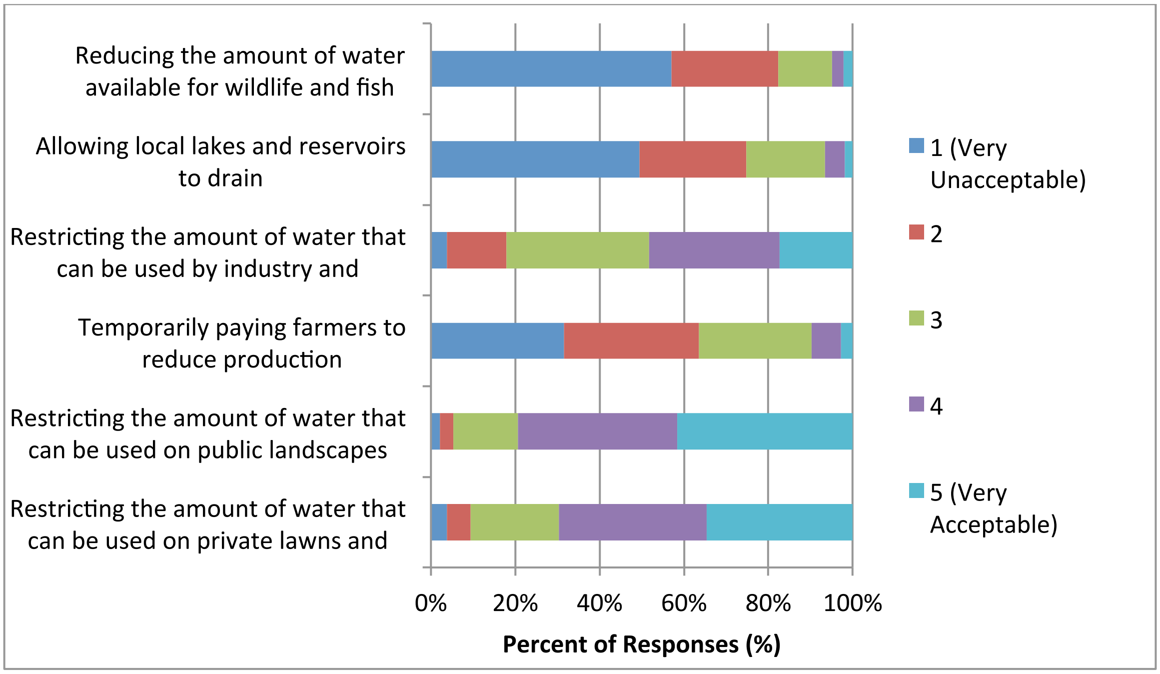


**Figure 24. Respondents' opinion about different water management programs**

**Table 34. Respondents' opinion about different water management programs**

| | 1 (Very Unacceptable) (%) | 2 | 3 | 4 | 5 (Very Acceptable) (%) | N |
|---|---|---|---|---|---|---|
| Restricting the amount of water that can be used on private lawns and landscapes | 3.8 | 5.6 | 21.0 | 34.9 | 34.7 | 786 |
| Restricting the amount of water that can be used on public landscapes | 2.2 | 3.1 | 15.3 | 37.8 | 41.6 | 783 |
| Temporarily paying farmers to reduce production | 31.6 | 32.0 | 26.6 | 7.0 | 2.8 | 782 |
| Restricting the amount of water that can be used by industry and business | 3.8 | 14.1 | 33.8 | 30.9 | 17.4 | 781 |
| Allowing local lakes and reservoirs to drain | 49.4 | 25.4 | 18.6 | 4.7 | 1.9 | 780 |
| Reducing the amount of water available for wildlife and fish habitats | 57.0 | 25.4 | 12.7 | 2.7 | 2.2 | 782 |

## During the resulting summer, how much would you be willing to reduce your household's water use in each of the following categories?

In times of water scarcity, water management programs may encourage or mandate reducing household water use. Therefore, respondents were asked to rate their willingness to voluntarily reduce their household's water use in the categories in Table 35 and Figure 25. Most respondents were willing to reduce their personal water use by a mean of 44.2% during times of water scarcity, with a preference toward reducing the use of a dishwasher and lawn watering.

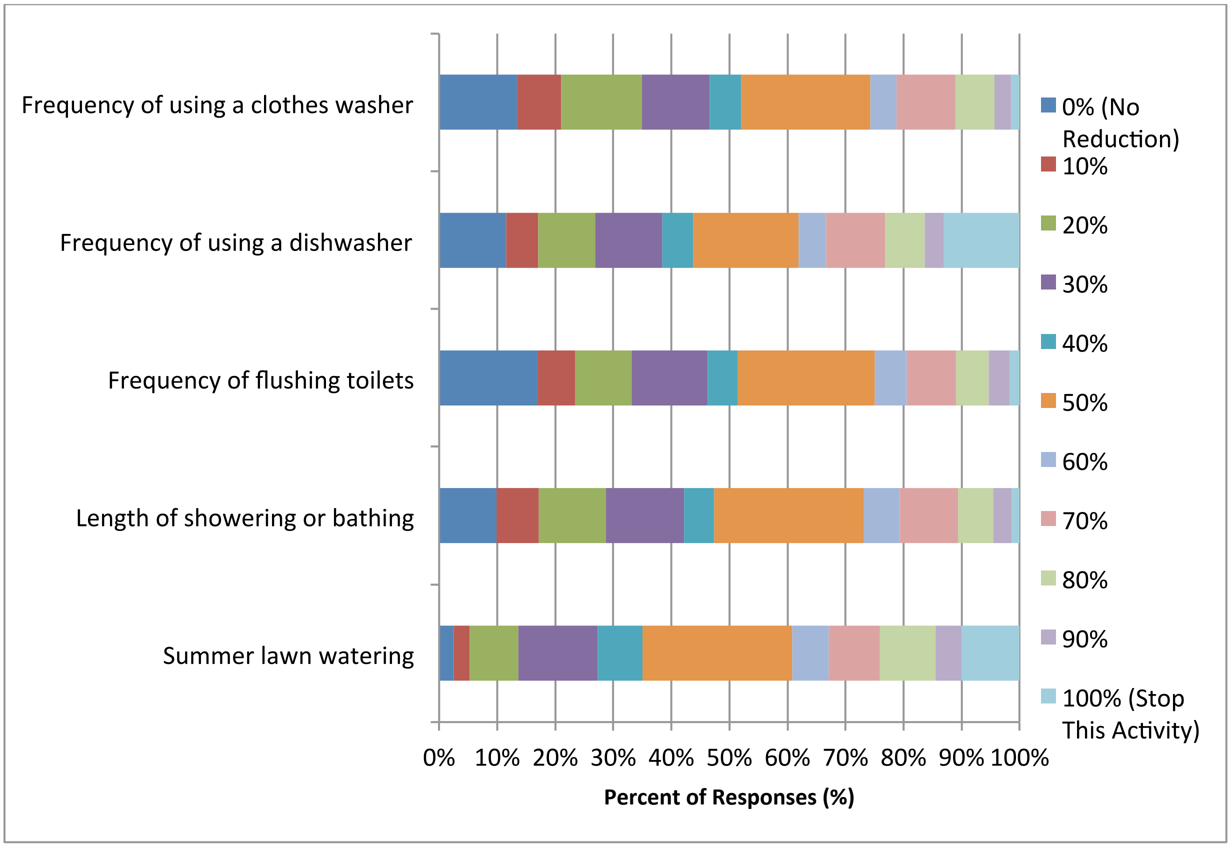


**Figure 25. Respondents' willingness to reduce household water use.**

**Table 35. Respondents' willingness to reduce household water use.**

| | No Reduction | | | | | | | | Stop this activity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0%** | **10%** | **20%** | **30%** | **40%** | **50%** | **60%** | **70%** | **80%** | **90%** | **100%** | $\bar{X}$ | **N** |
| Summer lawn watering | 2.5 | 2.8 | 8.3 | 13.7 | 7.7 | 25.8 | 6.3 | 8.8 | 9.6 | 4.4 | 10.1 | **53.66** | 636 |
| Length of showering or bathing | 9.9 | 7.3 | 11.5 | 13.5 | 5.2 | 25.8 | 6.1 | 10.1 | 6.0 | 3.2 | 1.4 | 41.85 | 784 |
| Frequency of flushing toilets | 17.0 | 6.4 | 9.8 | 13.1 | 5.2 | 23.5 | 5.6 | 8.4 | 5.7 | 3.6 | 1.7 | **39.09** | 784 |
| Frequency of using a dishwasher | 11.5 | 5.5 | 9.8 | 11.6 | 5.2 | 18.2 | 4.7 | 10.2 | 6.8 | 3.3 | 13.0 | 48.64 | 782 |
| Frequency of using a clothes washer | 13.4 | 7.6 | 14.0 | 11.6 | 5.5 | 22.2 | 4.6 | 10.1 | 6.8 | 2.8 | 1.5 | 39.57 | 785 |
| Sample MEAN ($\bar{X}$) | | | | | | | | | | | | **44.20** | |

## Now consider the appearance of your community during the same summer. How disturbing would it be to you if public green spaces turned brown?

Water management programs may mandate reducing outdoor irrigation of public spaces during times of water scarcity. Therefore, the questionnaire asked respondents to indicate how disturbing they would find public green spaces to be if these spaces turned brown. Responses selected either "very disturbing," "slightly disturbing," "neither disturbing nor not disturbing," "not disturbing," or "not at all disturbing" (Table 36; Figure 26). A large portion of respondents (39.4%) indicated that they would find brown public green spaces "slightly disturbing."

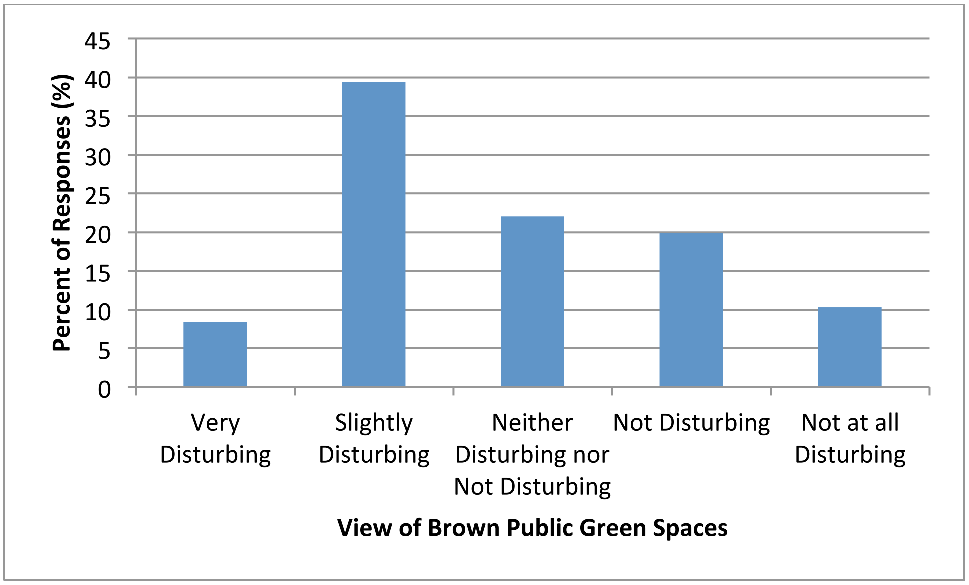


**Figure 26. Respondents' view of public green spaces turning brown.**

**Table 36. Respondents' view of public green spaces turning brown.**

| | **Frequency (%) (N=787)** |
|---|---|
| Very Disturbing | 8.4 |
| Slightly Disturbing | 39.4 |
| Neither Disturbing nor Not Disturbing | 22.0 |
| Not Disturbing | 19.9 |
| Not at all Disturbing | 10.3 |
| **Total** | 100.0 |

## How disturbing would it be to you if private green spaces turned brown?

Also, water managements programs may also limit outdoor irrigation of private green spaces. Respondents were asked to indicate hot disturbing they would find public green spaces to be if these spaces turned brown. Responses selected either "very disturbing," "slightly disturbing," "neither disturbing nor not disturbing," "not disturbing," or "not at all disturbing" (Table 37; Figure 27). A large portion of respondents (41.1%) indicated that they would find brown private green spaces "slightly disturbing."

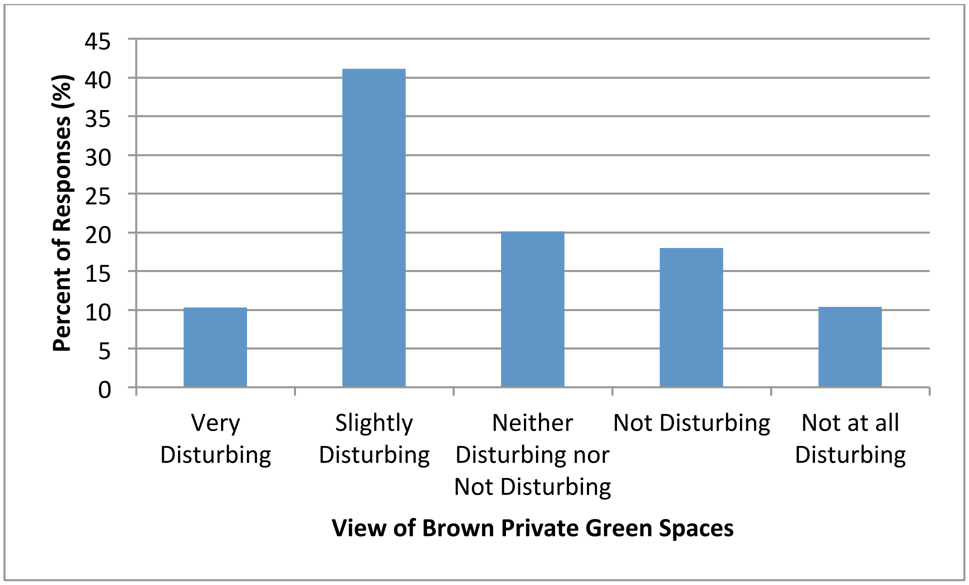


**Figure 27. Respondents' view of private green spaces turning brown.**

**Table 37. Respondents' view of private green spaces turning brown.**

| | Frequency (%) (N=785) |
|---|---|
| Very Disturbing | 10.3 |
| Slightly Disturbing | 41.1 |
| Neither Disturbing nor Not Disturbing | 20.1 |
| Not Disturbing | 18.0 |
| Not at all Disturbing | 10.4 |
| **Total** | 100.0 |

Figure 28 provides a comparison of respondents' view of public versus private green spaces. A sample t-test on the disturbance of public vs. private turning brown shows a significant difference between the two questions for alpha a priori of 0.015 (p=0.015). Respondents viewed brown private spaces as more disturbing that public.

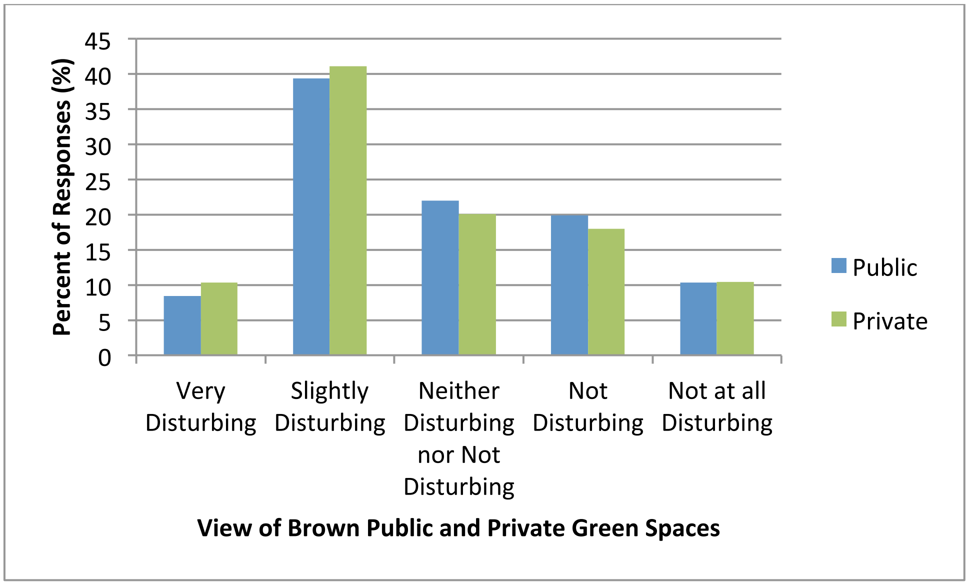


**Figure 28. View of public versus private green spaces turning brown.**

### For each of the following water uses, please indicate how <u>important</u> each is for the Okanagan basin in times of water scarcity?

For the above question, respondents were given a hypothetical situation where the Okanagan would continually receive about 20% less precipitation during the summer months. Respondents were asked to rate uses of water in Table 38 and Figure 29 from 1 (not very important) to 5 (very important). The majority of respondents indicated that "water for agriculture," "water for wildlife and that natural environment," and "water for household indoor use" are important for the Okanagan in times of water scarcity (either 4 or 5=very important).

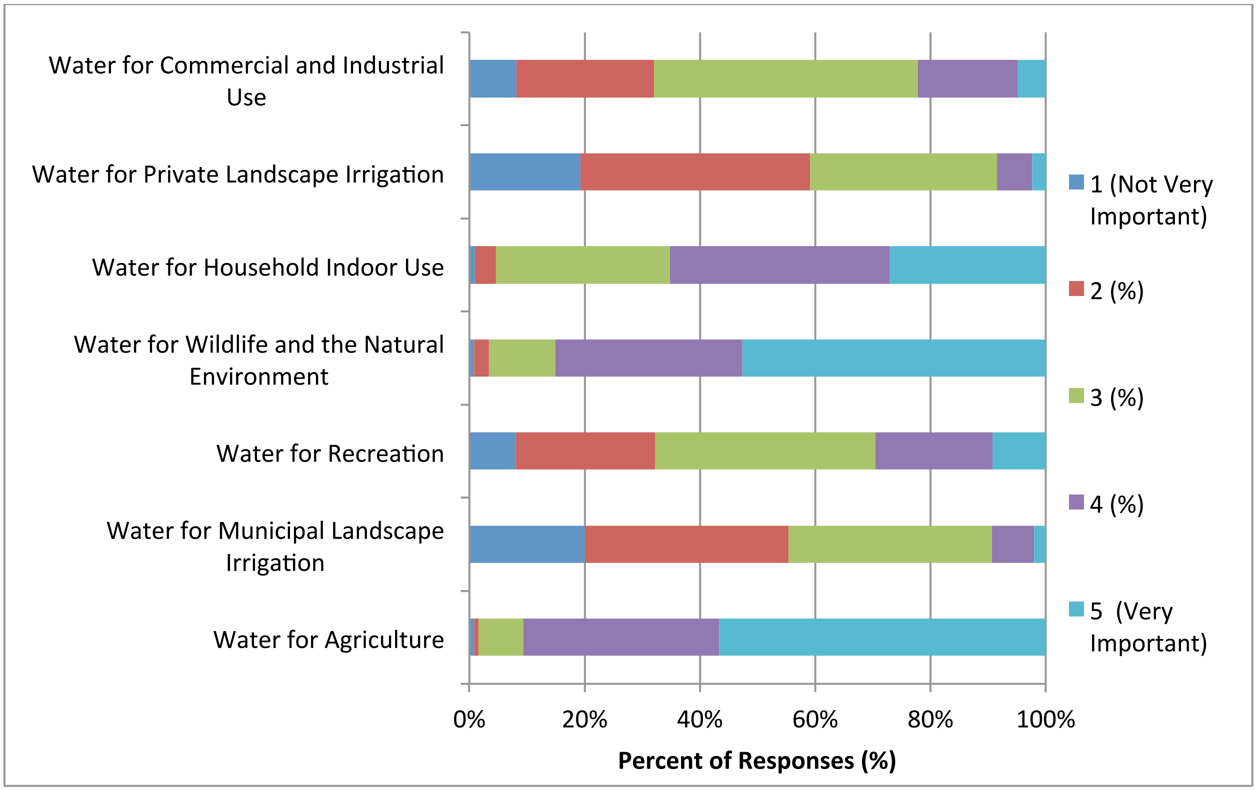


**Figure 29. Respondents' level of importance for uses.**

**Table 38. Respondents' level of importance for uses.**

| | Not Very Important | | | Very Important | | |
|---|---|---|---|---|---|---|
| | **1 (%)** | **2 (%)** | **3 (%)** | **4 (%)** | **5 (%)** | **N** |
| Water for Agriculture | 0.8 | 0.8 | 7.8 | 34.0 | 56.6 | 782 |
| Water for Municipal Landscape Irrigation | 20.0 | 35.3 | 35.3 | 7.3 | 2.0 | 784 |
| Water for Recreation | 8.0 | 24.3 | 38.1 | 20.4 | 9.2 | 785 |
| Water for Wildlife and the Natural Environment | 0.8 | 2.6 | 11.5 | 32.4 | 52.7 | 780 |
| Water for Household Indoor Use | 1.0 | 3.6 | 30.2 | 38.1 | 27.1 | 782 |
| Water for Private Landscape Irrigation | 19.3 | 39.8 | 32.4 | 6.0 | 2.4 | 783 |
| Water for Commercial and Industrial Use | 8.2 | 23.9 | 45.7 | 17.4 | 4.9 | 782 |

# Demographics

## Are you responsible for paying your water utility bill?

Almost all respondents (97.8%) are responsible for paying their water bill (Table 39).

Table 39. Respondents responsible for paying their water bill.

| | Frequency (%) (N=781) |
|---|---|
| Yes | 97.8 |
| No | 1.2 |
| I do not receive a water utility bill | 1.0 |
| **Total** | 100 |

## What is your gender?

The percentage of female (50.3%) and male (49.7%) respondents were relatively the same (Table 40).

**Table 40. Percentage of female and male respondents.**

| Gender | Frequency (%) (N=774) |
|---|---|
| Female | 50.3 |
| Male | 49.7 |
| **Total** | 100 |

## Which of the following age categories describes you?

Most respondents indicated that they were between the ages of "55 to 65" (34.0%) or "65 or over" (32.3%) (see Table 41). The next most frequent age category was "45 to 54" (26.7%). These results are relatively consistent with Kelowna's 2006 census data when 35% of the population was between the ages of 40 to 64 and 19% were 65 or over.

**Table 41. Respondents' age category.**

| | Frequency (%) (N=780) |
|---|---|
| Under 20 | 0.0 |
| 20 to 24 | 0.6 |
| 25 to 34 | 5.0 |
| 35 to 44 | 12.4 |
| 45 to 54 | 26.7 |
| 55 to 65 | 32.3 |
| 65 or over | 22.9 |
| **Total** | 100 |

## What is the highest level of education you have completed?

Most respondents had completed a trades or non-university certificate or diploma (34.8%), or university (21.4%) (see Table 42). Few respondents only completed high school (8.8%) or less than high school (1.3%).

**Table 42. Respondents' highest level of education.**

| | Frequency (%) (N=772) |
|---|---|
| Less than high school | 1.3 |
| Completed high school | 8.8 |
| Some post secondary education (post secondary not completed) | 18.0 |
| Trades or non-university certificate or diploma | 34.8 |
| Completed university | 21.4 |
| Post graduate degree | 15.7 |
| **Total** | 100 |

## Which of the following categories best describes your pre-tax annual household income?

Most respondents indicated that their household makes over $40,000 a year with a mean income between $60,000 and $100,000 (Table 43).

**Table 43. Respondents' pre-tax annual household income.**

| | Frequency (%) (N=714) |
|---|---|
| $19,999 or less | 3.4 |
| $20,000 to $39,999 | 8.4 |
| $40,000 to $59,999 | 14.7 |
| $60,000 to $79,999 | 16.4 |
| $80,000 to $99,999 | 17.6 |
| $100,000 to $125,999 | 18.5 |
| $130,000 to $149,999 | 9.8 |
| $150,000 to $199,999 | 3.2 |
| $200,000 to $249,999 | 6.6 |
| $250,000 or more | 1.4 |
| **Total** | 100 |

### Are you retired?

Close to a third of respondents indicated that they were retired (39.2%) (see Table 44). This is consistent with 2006 Canada census data.

**Table 44. Percentage of retired versus non-retired respondents.**

| | Frequency (%) (N=782) |
|---|---|
| **Yes** | 39.3 |
| **No** | 60.7 |
| **Total** | 100 |

# Appendix A – Complete alternative list and considerations

***Regional Issues and Requirements:***

- Arid and variable weather
- Climate change expectations:
  - Warmer winters
  - Lower snow pack
  - Earlier spring runoffs
  - Longer and drier growing seasons
  - Warmer temperatures
  - Lower summer rainfall
- Water management cooperatives and management/policy options that are supported by the public/water users
- Need for new water conservation and management regimes

***Water Demand Influences***

From (Turner et al., 2008)

- Weather and Climate
- Demographics and land use
  - Tourism
  - Occupancy densities
  - Population
  - Residential lot size
  - Housing type
- Water supply system
  - Pressure requirements and losses
- Water usage practices
  - Socio-cultural factors
  - Technical innovation
  - Knowledge and awareness
  - Regulation

    - Income
    - Restrictions
    - Pricing
- Source substitution
    - Industrial reuse
    - Greywater
    - Effluent use
    - Rainwater catchment
- Water using equipment
    - (Irrigation)
    - Appliances (stock and sales)

***What are the possible policy actions the region could take?***

- Improve system efficiency (leakage, pressure management)
- Modify water-use market
    - metering, billing and pricing
    - education and advisory services
    - Land use
- Improve residential water use efficiency (incentives, retrofit, regulation)
    - appliances and fixtures
    - landscapes and irrigation
- Improve business water use efficiency (incentives, retrofit, regulation)
- Substitute potable use (on-site or larger scale)
    - rain tanks and stormwater
    - grey water and effluent reuse
    - groundwater

## *What are the demand/conservation alternatives available for consideration?*

*Key: Demand Management Approach*

*System Efficiency*
*Improve water-use market*
*Improve residential water-use efficiency*
*Improve business water-use efficiency*
*Substitute potable use*
*Background conditions*

| # | Approach | Survey (Farmer/Resident) | Attribute | Attribute levels in experimental design | Related questions | Source |
|---|---|---|---|---|---|---|
| 1 | Background | Farmer/Resident | Water Availability | 20 % below norm<br>10 % below norm<br>10 % above norm<br>20 % above norm | | Review of regional drought plans |
| 2 | Business use | Farmer | Crop watering frequency (change in Xfreq) | - 20% waterings/month<br>-10 %waterings/month<br>zero change waterings/month<br>+ 10 % waterings/month<br>+ 20 % waterings/month | Status quo watering - waterings/m (reference)<br>[0–2] waterings/month<br>[2–4] waterings/month<br>[4–6] waterings/month<br>[6–8] waterings/month<br>>8 waterings/month<br>[8–10] waterings/month<br>[10–12] waterings/month<br>>12 waterings/month | Modified from (Barton & Bergland, 2010) |
| 3 | Residential use | Resident | Toilet Flushing Frequency (x/day) | 3 less per day<br>2 less per day<br>1 less per day<br>No change | Status quo toilet flushing<br>[0–2] flushes/day<br>[2–4] flushes/day<br>[4–6] flushes/day<br>[6–8] flushes/day<br>>8 flushes/day | North America Residential Water Usage Trends Since 1992 (Water RF prj 4031) (Coomes, Rockaway, Rivard, & Kornstein, 2010) |
| 4 | Business use | Farmer/Resident | Irrigation Management Requirement | Operator designed and installed<br>Designed by certified Irrigation Technician/installed by operator<br>designed and installed by certified Irrigation Technician | Irrigation system installed? Designed and installed by operator/technician? | Discussions with Stakeholder group<br><br>Adaptation of Kelowna water bylaws |
| 5 | Substitute potable use | Resident | % of resident irrigation irrigated with reuse water/grey water | 25%, 50%, 75%, 100% | | Review of Kelowna irrigation and water sustainability plans |

| # | Approach | Survey (Farmer/Resident) | Attribute | Attribute levels in experimental design | Related questions | Source |
|---|---|---|---|---|---|---|
| 6 | Residential use | Resident | % of turf area in outdoor landscape | 25%, 50%, 75%, 100% | Do you have a rain sensor installed as part of your irrigation system? | Review of Kelowna irrigation and water sustainability plans<br><br>Expansion of Kelowna water bylaws |
| 7 | Residential use | Resident | % of existing irrigation systems brought up to code | 25%, 50%, 75%, 100% | | Kelowna bylaws<br><br>(White & Fane, 2002) |
| 8 | Substitute potable use | Resident/Farmer | % of greenspace irrigated with reuse water | 25%, 50%, 75%, 100% | | (Thacher et al., 2010) |
| 9 | Residential | Resident | Reward for enrolment in conservation program (TBD) | Yes/No<br><br>Or<br><br>5 miles, 10 miles, 15 miles, 20 miles | Which of the following rewards programs would motivate you to enrol in a conservation management program:<br><br>Airmiles, rebate on monthly bill, rebates on water efficient fixtures (toilet, showerheads) | Discussion with OBWB |
| 10 | Residential use | Resident | Summer lawn irrigation restrictions | 1 waterings per week<br>2 waterings per week<br>3 waterings per week<br>4 waterings per week<br>no restrictions | Willingness to reduce water use in 5 categories (a) no reduction, (b) 10% reduction, or (c) 25% reduction.)<br><br>Categories: Lawn watering, Shower and bath, laundry, dishwasher use, toilet flushing<br><br>If lawn restrictions were made permanent, which restriction would you prefer?<br><br>Would you be willing to allow your water provider to control your irrigation systems based on monitoring local soil moisture conditions?<br><br>Would you let your lawn turn brown during summer? | (Haider & Rasid, 2002)<br><br>Review of Orange County Irrigation practices<br><br>Peak water management best practices<br><br>Adaption of water bylaws |
| 11 | Residential use | Resident | Assigned water days | Allowed every day<br>Every other day<br>3 days per week (Monday/Wednesday/Saturday or Tuesday/Thursday/Sunday)<br>2 days per week (Wednesday/Sunday or Tuesday/Saturday) | See above | Peak management best practices |

| # | Approach | Survey (Farmer/Resident) | Attribute | Attribute levels in experimental design | Related questions | Source |
|---|---|---|---|---|---|---|
| 12 | Residential Use | Resident | New development approvals conservation level | No requirement<br>20% below standard<br>40% below standard<br>60% below standard | | Review of Kelowna water sustainability plan linking conservation to development approvals |
| 13 | Residential Use | Resident | % rebate on purchase of new water efficient fixture/appliance | 25%, 50%, 75%, 100% | | Review of Kelowna water sustainability plan goal to Promote and Ensure the Use of Water Efficient Fixtures |
| 14 | Business Use | Farmer | % of farmers educated on irrigation best practices | 15%, 35%, 65%, 85% | | Derived from (Birol & Koundouri, 2008) (Birol & Koundouri, 2008)(Birol & Koundouri, 2008)Re-training farmers: In ecotourism and arid crop production |
| 15 | Business Use | Resident | % of residential/ commercial buildings conducting indoor water audit & retrofit | 15%, 35%, 65%, 85% | | Based on (White & Fane, 2002) |
| 16 | Residential Use | Resident | lawn management program feature | Irrigation restrictions<br>Maximum % turf area<br>Lawn replacement rebate | Would you remove your lawn if the above scenario was implemented? | Based on (Turner et al., 2008) |
| 17 | Background | Resident/Farmer | Appearance of urban environment | Brown in most public areas<br>Brown in some public areas<br>Green in all public areas | Perceptions on green landscaping<br><br>What do you think is reasonable for parks to pay for water? | Derived from (J Gordon, R Chapman, & Blarney, 2000)<br><br>Conservations with stakeholders |
| 18 | Substitute potable use | Resident/Farmer | Use of recycled water | None<br>Outdoor irrigation<br>Outdoor and agricultural irrigation<br>All irrigation and indoor use | | (Blamey, Jenny Gordon, & Ross Chapman, 1999) |
| 19 | Residential use | Resident | Indoor Rebate program | Showerhead<br>Toilet<br>Washing machine<br>Dishwasher | | Based on (Turner et al., 2008) |
| 20 | Residential Use | Resident | Outdoor rebate program | Rainwater tank<br>Rain sensor<br>Lawn buy back<br>Irrigation retrofit<br>Greywater | | Based on (Turner et al., 2008) |

| # | Approach | Survey (Farmer/Resident) | Attribute | Attribute levels in experimental design | Related questions | Source |
|---|---|---|---|---|---|---|
| 21 | Substitute potable use | Resident | Rainwater tank installation program | Voluntary with rebate<br>Voluntary with no rebate<br>Mandatory with no rebate<br>Mandatory with rebate | Questions on source substitution | Derived from OBWB conservation materials |
| 22 | Residential Use | Farmer | Reduction in urban water use | None<br>10%<br>20%<br>30% | | Comparison between urban and agricultural Beneficial use |
| 23 | Business Use | Resident | Agricultural Efficiency transfers (Transfer of efficiency savings to urban environment) | None<br>10%<br>20%<br>30% | | Derived from (Turner et al., 2008)Comparison between urban and agricultural Beneficial use |
| 24 | Residential use/ Business use | Resident/Farmer | No. of inspectors<br>Ratio: inspector per household | 1:1000<br>1:2000<br>1:5000<br>1:8000<br>1:50,000<br>1:200,000 | In support of the policy to "Do Not Support Unauthorized Use of Water" should BC have a mandate to check if users are in compliance with the Water Act.? | (Cooper, J. Rose, & Crase, 2011)<br><br>(Gulik, 2009) |
| 25 | Background | Resident/Farmer | Change in Water bill<br>$ per annum | -$100<br>-$50<br>no change<br>$50<br>$100 | | (Cooper et al., 2011), WTA principals |
| 27 | Water use Market | Resident/Farmer | Urban Density | 1 person per acre<br>2-10 people per acre<br>11 – 50 people per acre<br>50 people per acre<br><br>Or Visual image representing density | | Stakeholder interests regarding population density and zoning – Factors in water demand (Turner et al., 2008) |
| 28 | Business use | Farmer | Irrigation Scheduling Support | - Farmer determines irrigation schedules<br>- Water provider provides irrigation schedules<br>- Use irrigation calculator to determine irrigation schedule<br>- Okanagan irrigation management tool provides irrigation schedules | | Stakeholder interviews |
| 29 | Business use | Farmer | Rebate on irrigation installation or retrofit | 10%<br>20%<br>30%<br>40% | Given the above scenario would you install new irrigation systems or retrofit your existing system? | Stakeholder interviews |

| # | Approach | Survey (Farmer/Resident) | Attribute | Attribute levels in experimental design | Related questions | Source |
|---|---|---|---|---|---|---|
| 30 | Water use market | Farmer/Resident | Policy Instrument | - Land use planning<br>- Improve residential water use efficiency<br>- Improve agricultural/industry water use efficiency<br>- Invest in new water sources (rain tanks, greywater, groundwater) | | Modified from Birol (Birol & Koundouri, 2008) |
| 31 | Residential/Business use | Farmer/Resident | Water Use data | No data provided<br>Yearly data provided<br>Monthly data provided<br>Realtime information (smart meters) | | Stakeholder workshops |
| 32 | Business Use | Farmer | Water Use limit policy implemented (per crop type) | For new land acquisitions<br>For existing land uses<br>For all uses (based on regional average) | Would you switch crops if the above scenario was implemented? - Converted to question | Review of land use and water allocation priorities |
| 33 | Business use | Farmer | Annual allocation and peak withdrawal rate limits | For new licenses<br>Existing and new licenses<br>None | Should groundwater withdrawals be included in annual licensing limits? | (Gulik, 2009) |
| 34 | Business use | Farmer | Adaptive water licenses adjusted | Annually<br>Seasonally<br>Quarterly<br>Monthly | | Stakeholder workshops<br><br>Adaptive from (Gulik, 2009) |
| 35 | Business Use | Farmer | License trading allowed between farmers during drought | yes<br>no | | Stakeholder workshops<br><br>Adaptive from (Gulik, 2009) |
| 36 | Background Conditions/Risk | Farmer | Change in the # days unable to irrigate crops | 10% more<br>20% more<br>10% less<br>20% less | | Measuring risk (Mansfield & Pattanayak, 2006) |

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# Appendix E.

# Okanagan BC Agricultural Questionnaire

*The following is the paper version of the Okanagan BC Agricultural questionnaire sent to survey contacts not able to access the survey website watersurvey.ca. The questionnaire, paper version and online version, was used to collect stated preference data from farmers on drought response plan features described in Chapter 3 and responses are detailed in Appendix F.*

# Agricultural Water in BC
# What is important to you?

In collaboration with the **BC agricultural community** and the many partners shown below, **Simon Fraser University** is currently conducting a survey on agricultural water use in British Columbia. This survey provides you the opportunity to give input in future water policies.

This project (2011s0575) has received ethics approval by the Research Ethics Board at Simon Fraser University. By filling out this questionnaire, you are consenting to participate. Your participation in this survey is voluntary, and you may choose not to respond to any question or terminate the survey at any time. All information that you provide in this survey will be kept strictly confidential in accordance with Simon Fraser University's research ethics guidelines. Please review the Privacy Policy at the end of this survey before starting the survey. Also review and make note of the "Contact Information" provided in case you have any questions or concerns for the researchers.

**Contact Information**
**(See page 19)**

**Privacy Policy**
**(See page 19)**

# To begin, please tell us about your farming experience

This survey discusses agricultural water use in British Columbia. In this survey we encourage you to consider all the farms you operate as your farm. This includes all irrigated and non irrigated land, producing or non-producing, used for forage crops, fruits, vegetables, field crops, hay and improved pasture, on land owned, rented or leased from others. If you own or operate farms in many different regions, consider only your farms in the Thompson-Okanagan region.

1. **For how many years have you been farming?**
   *Please write the number of years below.*

   ____________________________

2. **For how many years have you been farming in the Thompson-Okanagan region?**
   *Please write the number of years below.*

   ____________________________

3. **For how many years do you plan to continue farming in the Thompson-Okanagan region?**
   *Please select one response only.*

   - ☐ Less than 5 years
   - ☐ 5 to 10 years
   - ☐ 11 to 15 years
   - ☐ 16 to 20 years
   - ☐ More than 20 years
   - ☐ Do not know

4. **What will likely happen to your farm after you stop farming?**
   *Please select one response only.*

   - ☐ Have a family successor take over the farm
   - ☐ Retain ownership but lease farm or land
   - ☐ Sell
   - ☐ Have not yet started planning for retirement from farming
   - ☐ Do not know
   - ☐ Other (*please describe*) → ________________________________________

# Please tell us about your farmland

**5. What types of crops do you farm?**
*Please write the approximate acreage of each crop type cultivated on your farm. For each crop, please write the primary irrigation equipment used to irrigate each crop type, selecting the closest match from the following list.*

1. Overhead solid set sprinkler
2. Under-tree solid set sprinklers
3. Handmove or wheelmove sprinklers
4. Pivot sprinklers
5. Travelling gun(s)
6. Stationary gun(s)
7. Solid set gun
8. Drip irrigation
9. Microjet
10. None
11. Other equipment not listed

| Crop type | Total Acreage | Primary Irrigation Equipment |
|---|---|---|
| Forage | ________(acres) | ________________ |
| Orchard | ________(acres) | ________________ |
| Vineyard | ________(acres) | ________________ |
| Vegetable | ________(acres) | ________________ |
| Greenhouse | ________(acres) | ________________ |
| Other Perennial | ________(acres) | ________________ |
| Other Annual | ________(acres) | ________________ |
| Other crop(s) ________________ | ________(acres) | ________________ |

**6. Do you own or lease other non-irrigated land or non-utilized irrigation licenses?**
*Please enter the approximate acreage of each.*

| | Total Acreage |
|---|---|
| Other non-irrigated marginal land | ________(acres) |
| Other non-arable land | ________(acres) |
| Other non-utilized irrigation licenses | ________(acres) |

**7. What are your intentions for your farm in the next 5 years?**
*Please select one response only.*

- ☐ Increase production
- ☐ Maintain current level of production
- ☐ Decrease production

# Please tell us about irrigation on your farm

**8. What is your farm's <u>primary</u> source of irrigation water?**
*Please select one response only.*

- ☐ A groundwater well
- ☐ A surface water license
- ☐ A municipal, regional, or district water provider (*please name*) → ____________________
- ☐ Do not know
- ☐ Other (*please describe*) → ________________________________________

**9. How often have you experienced any water shortages on your farm in the last 10 years?**
*Please indicate how often on a scale of (1 = never) to (5 = very often).*

| | Never 1 | 2 | 3 | 4 | Very Often 5 |
|---|---|---|---|---|---|
| Water shortages have affected my farm... | ☐ | ☐ | ☐ | ☐ | ☐ |

**10. If you have experienced water shortages, to what extent were the water shortages caused by any of the following issues?**
*Please rate how each statement affected your farm.*

| | Not at all 1 | 2 | 3 | 4 | Very much so 5 |
|---|---|---|---|---|---|
| Shortage of surface water | ☐ | ☐ | ☐ | ☐ | ☐ |
| Shortage of groundwater (including shallow wells and deep wells) | ☐ | ☐ | ☐ | ☐ | ☐ |
| Poor water quality | ☐ | ☐ | ☐ | ☐ | ☐ |
| High cost of obtaining water | ☐ | ☐ | ☐ | ☐ | ☐ |
| Irrigation restrictions | ☐ | ☐ | ☐ | ☐ | ☐ |
| Other (*please describe*) → ____________________ ________________________________________ | ☐ | ☐ | ☐ | ☐ | ☐ |

# Tell us about your water source

***If you answered "A municipal, regional, or district water provider," to question 8, skip to question 14 on page 6.***

**11. What license priority do you believe you have on your primary source of irrigation water?**
*Please select one response only.*

☐ Low priority
☐ Medium priority
☐ High priority

**12. Do you have a license to store water in support of your primary source of irrigation water?**
*Please select one response only.*

☐ Yes
☐ No

**13. Would you be comfortable reporting the water you withdraw from your primary source of irrigation water?**
*Please select one response only.*

☐ Yes
☐ No

# Your Opinion on Water Use in your region

**14. How much do you agree or disagree with each of the following statements about managing the Thompson-Okanagan region's water resources?**
*For each statement, please select one option.*

| | Strongly Agree | Agree | Neither Agree nor Disagree | Strongly Disagree | No Opinion |
|---|---|---|---|---|---|
| Water restrictions should be voluntary rather than mandated by the government | ☐ | ☐ | ☐ | ☐ | ☐ |
| Regional land use and water planning is needed to manage water scarcity | ☐ | ☐ | ☐ | ☐ | ☐ |
| Growth of cities should be limited to manage water scarcity | ☐ | ☐ | ☐ | ☐ | ☐ |
| Public money should be used to develop or acquire new water resources | ☐ | ☐ | ☐ | ☐ | ☐ |
| I am satisfied with the current system of water management | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water policy makers understand my priorities for water use | ☐ | ☐ | ☐ | ☐ | ☐ |

**15. How much do you agree or disagree with each of the following statements about water licensing?**
*For each statement, please select one option.*

| | Strongly Agree | Agree | Neither Agree nor Disagree | Strongly Disagree | No Opinion |
|---|---|---|---|---|---|
| I understand the current water licensing system in British Columbia well | ☐ | ☐ | ☐ | ☐ | ☐ |
| I believe other farmers understand the current water licensing system in British Columbia well | ☐ | ☐ | ☐ | ☐ | ☐ |

# Your Opinion on changing water policy

*As part of its discussion with the agricultural community on modernizing the 1909 Water Act, the BC Government proposed enabling **Agricultural Water Reserves** to ensure adequate water supplies for the agricultural community.*

*The BC Agriculture Council, an involved stakeholder, suggests defining an agricultural water reserve as:*

"AWR is an allocation of [ground and surface] water for agricultural lands in the Agricultural Land Reserve or areas zoned for agriculture that is held for agriculture's use in perpetuity. Agricultural use includes irrigation of crops, crop washing, livestock watering or other agricultural activities such as frost protection and crop cooling. Future water demand for increased livestock or an increased irrigated land base will be included in the reserve providing that there is sufficient water available to be licensed as determined through a watershed based management planning process." – *BCAC*

**16. Do you support the development of an agricultural water reserve in British Columbia?**
*Please select one response only.*

☐ Yes
☐ No

**17. How much do you agree or disagree with the following statement about establishing an agricultural water reserve?**
*For each statement, please select one option.*

| | Strongly Agree | Agree | Neither Agree nor Disagree | Strongly Disagree | No Opinion |
|---|---|---|---|---|---|
| I would participate in a watershed planning process to establish an agricultural water reserve in my area | ☐ | ☐ | ☐ | ☐ | ☐ |

**18. If an agricultural water reserve was established in the Thompson-Okanagan region, how likely would you be to...**
*Please indicate how likely it is that you would take each action on a scale of (1 = not at all likely) to (5 = very likely).*

| | Not likely at all 1 | 2 | 3 | 4 | Very likely 5 |
|---|---|---|---|---|---|
| ... decrease the amount of water you use on your farm | ☐ | ☐ | ☐ | ☐ | ☐ |
| ... increase the amount of land you irrigate | ☐ | ☐ | ☐ | ☐ | ☐ |

# Your Opinion on Changing Climate in your region

**19. Which of the following statements most accurately reflects your opinion about climate change in the Thompson-Okanagan region?**
*Please select one response only.*

☐ Yes, climate change will happen, but its indications will only become apparent later.
☐ Yes, climate change is happening; first indications are apparent already.
☐ The statements about climate change are too uncertain. It is too early to have an opinion about it.
☐ No, I do not believe in climate change.
☐ Other (*please describe*) → ____________________________________________

**20. Have you noticed any changes to the following items in the Thompson-Okanagan region?**
*For each statement, please select one option.*

| | Increased | Not Changed | Decreased | Do not know |
|---|---|---|---|---|
| The amount of rainfall during the summer has... | ☐ | ☐ | ☐ | ☐ |
| The severity of winters has... | ☐ | ☐ | ☐ | ☐ |
| The frequency of water shortages has... | ☐ | ☐ | ☐ | ☐ |
| The length of the growing season has... | ☐ | ☐ | ☐ | ☐ |
| The frequency of extreme weather events (droughts, freezes, flooding) has... | ☐ | ☐ | ☐ | ☐ |
| The number of pests has... | ☐ | ☐ | ☐ | ☐ |
| The occurrence of early blooming has... | ☐ | ☐ | ☐ | ☐ |

# Your Opinion on Changing Climate in your region

*Climate change could increase the occurrence of drought in regions of British Columbia. Such changes could reduce the amount of water available for all uses and water managers may consider ways to manage and respond to water shortages.*

**21. To reduce the impact from water shortages, how <u>acceptable</u> would each of the following management responses be to you?**

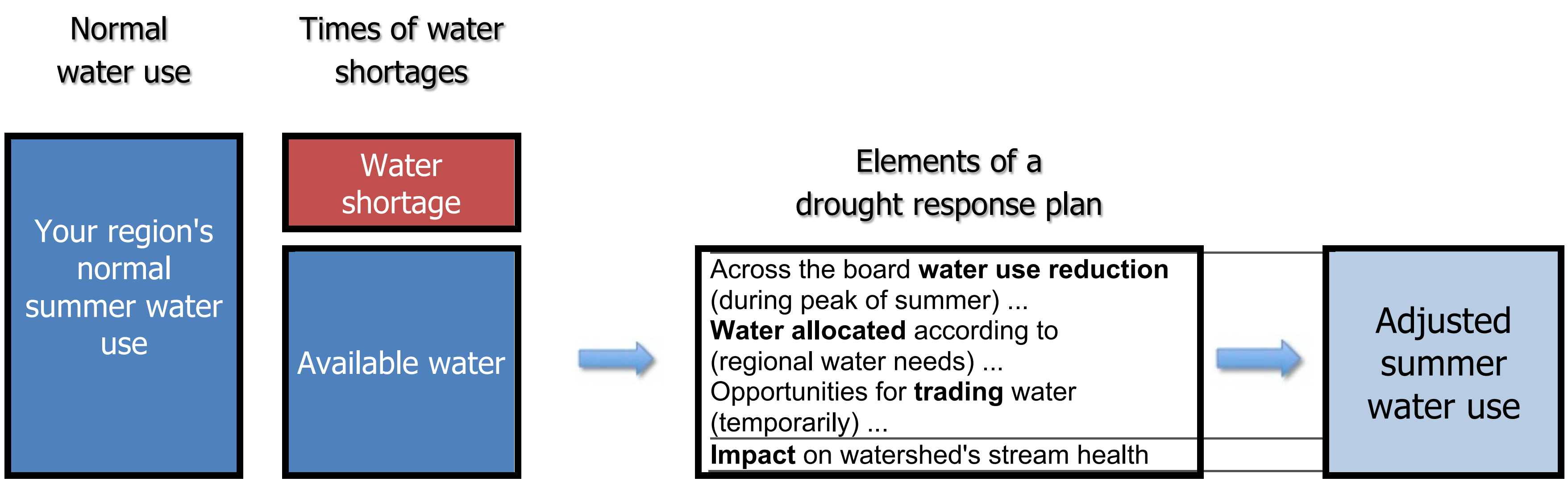
*Please rate your acceptance of each management response on a scale from (1 = very unacceptable) to (5 = very acceptable).*

| | Very unacceptable 1 | 2 | 3 | 4 | Very acceptable 5 |
|---|---|---|---|---|---|
| Providing incentives (payouts) for water users to purchase technologies that use water more efficiently | ☐ | ☐ | ☐ | ☐ | ☐ |
| Constructing additional reservoirs for more water storage | ☐ | ☐ | ☐ | ☐ | ☐ |
| Providing incentives for producers to not irrigate during droughts | ☐ | ☐ | ☐ | ☐ | ☐ |
| Reducing water for wildlife habitat in and around streams and rivers during droughts | ☐ | ☐ | ☐ | ☐ | ☐ |
| Requiring water use reductions during droughts | ☐ | ☐ | ☐ | ☐ | ☐ |
| Providing an opportunity for regions to adjust how water is allocated during droughts | ☐ | ☐ | ☐ | ☐ | ☐ |
| Providing incentives for producers to plant more drought- resistant crops | ☐ | ☐ | ☐ | ☐ | ☐ |
| Improving reporting of water use by producers | ☐ | ☐ | ☐ | ☐ | ☐ |
| Investing in drought education programs | ☐ | ☐ | ☐ | ☐ | ☐ |
| Providing an opportunity for producers to trade water during droughts | ☐ | ☐ | ☐ | ☐ | ☐ |

# Selecting a drought response plan - EXAMPLE

*Currently, the BC government proposes to give regional water users more flexibility to develop their own drought response plans for times when their water requirements can no longer be met.* ***Imagine that you are working with a group of other farmers in your region to develop such a drought response plan.***

*The diagram below illustrates how a drought response plan will address a water shortage to reduce the amount of water used and also considers the health of the environment.*




*In the next section of this survey, you will be presented with* ***several possible drought response plans.*** *See next page for* ***an example.***

# Selecting a drought response plan - EXAMPLE

*The elements of **Plan A** and **Plan B** will differ on each of the following pages. While some of the plans may not seem ideal, each one of them could occur under certain circumstances. During a water shortage the priority of licenses might not apply; any loss of seniority rights would be compensated.*

*There are no right or wrong answers to these special type of research questions but it is important to regard them as real-world situations, in which the selected plan affects your farm(s). You will be asked to complete a total of six evaluations (we need these for rigorous statistical analysis). At any point you may familiarize yourself with the elements of the plan using in the following table.*

| | |
|---|---|
| Across the board **water use reduction** (during peak of summer) ... | *- Across the board reductions in all allocations as a % of farm water allocations.* |
| **Water allocated** according to (regional water needs) ... | *- Allocation of agricultural water during water shortages is based on proportion distributions, crop value, or sensitivity to water loss.* |
| Opportunities for **trading** water (temporarily) ... | *- System for allowable temporary water trades between license holders, managed between famers, or between all water users in the region.* |
| **Impact** on watershed's stream health | *- Impact (low, moderate, or high impact) on overall stream health and aquatic environments* |

| *Likelihood of water shortage occurring* | **1 in 5 years** | |
|---|---|---|
| Elements of a drought response plan | **Plan A** | **Plan B** |
| Across the board **water use reduction** (during peak of summer) ... | 30% | 15% |
| **Water allocated** according to ... | sensitivity of crop to water loss | crop value |
| Opportunity for **trading** water ... | between farmers | none |
| **Impact** on watershed's stream health | low | high |
| Please choose one ➔ | ☐ | ☐ |

EXAMPLE

# Selecting a drought response plan – 1 of 6

**22. Given the likelihood of a water shortage occurring in your region, which drought plan would you select?**
*Please select one plan only.*

| *Likelihood of water shortage occurring* | **1 in 15 years** | |
|---|---|---|
| Elements of a drought response plan | **Plan A** | **Plan B** |
| Across the board **water use reduction** (during peak of summer) ... | 30% | 15% |
| **Water allocated** according to ... | sensitivity of crop to water loss | proportional distributions |
| Opportunity for **trading** water ... | between all users | none |
| **Impact** on watershed's stream health | low | moderate |
| Please choose one ➔ | ☐ | ☐ |

**23. What would you do if a water shortage occurred and the plan you selected above was implemented?**
*Select any action you would take.*

- Invest in converting part or all of my farm to crops with lower water requirements ☐
- Invest in improving my irrigation system's water efficiency ☐
- Temporarily trade my water rights to someone else for the irrigation season ☐
- Stop irrigating my crops for one or several months ☐
- Invest in increasing my farm's water storage capacity ☐
- Reduce the amount of irrigated land I farm ☐

# Selecting a drought response plan – 2 of 6

**24. Given the likelihood of a water shortage occurring in your region, which drought plan would you select?**
*Please select one plan only.*

| *Likelihood of water shortage occurring* | **1 in 10 years** | |
|---|---|---|
| Elements of a drought response plan | **Plan A** | **Plan B** |
| Across the board **water use reduction** (during peak of summer) ... | 15% | 0% |
| **Water allocated** according to ... | Crop value | sensitivity of crop to water loss |
| Opportunity for **trading** water ... | between farmers | between farmers |
| **Impact** on watershed's stream health | moderate | high |
| Please choose one ➔ | ☐ | ☐ |

**25. What would you do if a water shortage occurred and the plan you selected above was implemented?**
*Select any action you would take.*

| | |
|---|---|
| Invest in converting part or all of my farm to crops with lower water requirements | ☐ |
| Invest in improving my irrigation system's water efficiency | ☐ |
| Temporarily trade my water rights to someone else for the irrigation season | ☐ |
| Stop irrigating my crops for one or several months | ☐ |
| Invest in increasing my farm's water storage capacity | ☐ |
| Reduce the amount of irrigated land I farm | ☐ |

# Selecting a drought response plan – 3 of 6

**26. Given the likelihood of a water shortage occurring in your region, which drought plan would you select?**
*Please select one plan only.*

| *Likelihood of water shortage occurring* | **1 in 5 years** | |
|---|---|---|
| Elements of a drought response plan | **Plan A** | **Plan B** |
| Across the board **water use reduction** (during peak of summer) ... | 0% | 30% |
| **Water allocated** according to ... | proportional distributions | crop value |
| Opportunity for **trading** water ... | none | between all users |
| **Impact** on watershed's stream health | high | low |
| Please choose one ➔ | ☐ | ☐ |

**27. What would you do if a water shortage occurred and the plan you selected above was implemented?**
*Select any action you would take.*

| | |
|---|---|
| Invest in converting part or all of my farm to crops with lower water requirements | ☐ |
| Invest in improving my irrigation system's water efficiency | ☐ |
| Temporarily trade my water rights to someone else for the irrigation season | ☐ |
| Stop irrigating my crops for one or several months | ☐ |
| Invest in increasing my farm's water storage capacity | ☐ |
| Reduce the amount of irrigated land I farm | ☐ |

# Selecting a drought response plan – 4 of 6

**28. Given the likelihood of a water shortage occurring in your region, which drought plan would you select?**
*Please select one plan only.*

| *Likelihood of water shortage occurring* | **1 in 10 years** | |
|---|---|---|
| Elements of a drought response plan | **Plan A** | **Plan B** |
| Across the board **water use reduction** (during peak of summer) … | 30% | 30% |
| **Water allocated** according to … | sensitivity of crop to water loss | crop value |
| Opportunity for **trading** water … | between all users | between farmers |
| **Impact** on watershed's stream health | low | high |
| Please choose one ➔ | ☐ | ☐ |

**29. What would you do if a water shortage occurred and the plan you selected above was implemented?**
*Select any action you would take.*

- Invest in converting part or all of my farm to crops with lower water requirements ☐
- Invest in improving my irrigation system's water efficiency ☐
- Temporarily trade my water rights to someone else for the irrigation season ☐
- Stop irrigating my crops for one or several months ☐
- Invest in increasing my farm's water storage capacity ☐
- Reduce the amount of irrigated land I farm ☐

# Selecting a drought response plan – 5 of 6

**30. Given the likelihood of a water shortage occurring in your region, which drought plan would you select?**
*Please select one plan only.*

| *Likelihood of water shortage occurring* | **1 in 5 years** | |
|---|---|---|
| Elements of a drought response plan | **Plan A** | **Plan B** |
| Across the board **water use reduction** (during peak of summer) … | 15% | 15% |
| **Water allocated** according to ... | crop value | proportional distributions |
| Opportunity for **trading** water ... | between farmers | between all users |
| **Impact** on watershed's stream health | moderate | low |
| Please choose one ➔ | ☐ | ☐ |

**31. What would you do if a water shortage occurred and the plan you selected above was implemented?**
*Select any action you would take.*

- Invest in converting part or all of my farm to crops with lower water requirements ☐
- Invest in improving my irrigation system's water efficiency ☐
- Temporarily trade my water rights to someone else for the irrigation season ☐
- Stop irrigating my crops for one or several months ☐
- Invest in increasing my farm's water storage capacity ☐
- Reduce the amount of irrigated land I farm ☐

*This last section asks for some limited personal details to enable important statistical analysis. These questions will help us understand the opinions of smaller groups within our larger sample. Individual responses will not be published. As a reminder, responses to these questions and all other questions will be treated anonymously and kept strictly confidential.*

**34. What is the ownership status of the land where your farm is located?**
*Please select all that apply.*

☐ Land that is owned by the producer.
☐ Land that is leased or rented
☐ Land owned by the Crown
☐ Other (*please describe*) → ___________________________________________

**35. What is your relationship to the farm?**
*Please select all that apply.*

☐ I am an owner/lessee of the farm.
☐ I am an employee of the farm
☐ I am family member to the farmer
☐ Other (*please describe*) → ___________________________________________

**36. What percentage of your total income comes from on-farm sources?**
*Please select one response only.*

☐ 0%
☐ 1 to 24%
☐ 25% to 49%
☐ 50% to 74%
☐ 75% to 99%
☐ 100%

**37. Which of the following age categories describes you?**
*Please select one response only.*

☐ Under 20
☐ 20 to 24
☐ 25 to 34
☐ 35 to 44
☐ 45 to 54
☐ 55 to 65
☐ Over 65

## *Last Words*

**If you have any suggestions or additional comments regarding this survey, we would appreciate to know about it.**

______________________________________________________________________________

______________________________________________________________________________

# Appendix F.

# Assessing Water Use Preferences to Water Conservation Policy and Implementation Strategies

*The following was previously published as Conrad, S. (2013). "Assessing Water Use Preferences to Water Conservation Policy and Implementation Strategies". Victoria, BC. Simon Fraser University & Investment Agriculture Foundation of British Columbia in support of this thesis at the conclusion of the BC agricultural survey presented in chapter 3. I was the sole author of the work.*

SFU SCHOOL OF RESOURCE AND ENVIRONMENTAL MANAGEMENT

# *Assessing Water Use Preferences to Water Conservation Policy and Implementation Strategies*

**FINAL PROJECT REPORT**
**REVISED SEPTEMBER 2013**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*Funding provided by:*

Canada | Investment Agriculture Foundation of British Columbia | British Columbia The Best Place on Earth

**Report Overview**

This report provides a summary of the Agriculture Environment and Wildlife Fund (AEWF) project – *Assessing Water Use Preferences to Water Conservation Policy and Implementation Strategies*. This revised report covers work through September 31, 2013 and supersedes all previous reports.

**Report Organization**

This report is organized in two sections and three appendixes:

Section 1: ***Overview and Highlights*** presents a synopsis of the study results

Section 2: ***Methodology*** highlights the methodologies used to conduct the study

Section 3: ***Detailed Data Results*** presents complete outcomes from each component of the study questionnaire

## *List of Figures*

## *List of Tables*

## 1. Overview and Highlights

The purpose of this project was to connect with residential and agricultural water users in the Okanagan basin, British Columbia to determine perceptions and preferences of water demand management alternatives and to gauge which alternatives residents and farmers would most readily accept. This project was jointly funded through the Natural Resources Canada's (NRCAN) Regional Adaptation Collaborative Program and as an activity of the Agriculture Environment and Wildlife Fund component of the Agri-Food Futures Fund. The 2012 NRCAN report: *Assessing the effectiveness of climate change adaptation policies: a survey of residential preferences* provides a summary of residential findings while this report focuses on farmer attitudes. Highlights from the NRCAN report are included in this report and a copy of the 2012 Okanagan Water Study: *Resident Descriptive Statistics report* is included as an appendix.

**Project Objectives:**

- Identify water policy alternatives for achieving management goals in the Okanagan Basin that can be applied generally;
- Determine water user preferences for water policy alternatives using stated preference choice analysis;
- Investigate a process for identifying and quantifying agricultural water use preferences that can be replicated across BC and other parts of Canada;

To accomplish these objectives, the project examined the factors affecting the willingness of farmers to adopt alternative water irrigation practices and plan for water scarce events. Through a combination of workshops, one-on-one interviews, and short surveys this project found that farmers *are* willing to consider water conservation measures in order to secure a viable agricultural future. This section highlights findings from an extensive dialogue with farmers in the Okanagan as well as relevant findings from the related residential survey.

**Significant Findings:**

Dialogue with the Okanagan agricultural and residential community revealed a complex social and physical relationship between agricultural and domestic water use. Fast growing residential areas are exerting pressure on agricultural uses of water and yet residents recognize the importance of agriculture. Irrigation districts must increasingly balance providing safe drinking water and sufficient water supplies to meet agricultural demands. In addition, climate change presents increased risk of water shortages and elevates the priority for developing management strategies supporting utilizing water efficiently.

Numerous stakeholder workshops and interviews (see section 2 for a complete listing) revealed several themes around climate change adaptation and water conservation management. First, residents of the Okanagan generally believe that climate change is occurring, winters are less severe and water scarcity severity has increased in the last 10 years. In the short term, study participants prioritize water use for agricultural irrigation, water for the environment, and personal health over landscape watering. To address long-term water scarcity, participants prefer a combination of water use behaviour changes, investing in new water supplies with public dollars, and managing the growth of cities. Participants were not adverse to water restriction mandates but do find draining local lakes and reservoirs and reducing the amount of water for the environment unacceptable.

Focus groups illustrated a general lack of consideration for water and climate policy measures in the region. For instance, only 1 out of the many participants present at the various focus group meetings had reviewed their water bill in the last year and many commented that water shortages were not an issue of climate but – incorrectly – due to International water treaties. Farmer focus groups expressed a strong willingness to work with water providers on water efficiency measures with the assurance that efficiency gains would not be allocated to other uses.

Focus groups also revealed that while there are numerous climate policy and management options, regional understanding of these options is key. Overcoming the lack of awareness is needed before options can be proposed or even understood well enough by water users to form a preference. The level of understanding of policy options led to the elimination of several from the study (such as top soil augmentation, water reuse, xeriscaping policies, and remote irrigation scheduling), as they were not well understood and or mistrusted by residents and farmers.

**Reoccurring Themes:**

***Resistance toward water management efforts***: One reoccurring theme expressed by farmers was resistance toward water management efforts as many farmers felt they were already using water efficiently, even when acknowledging that irrigation technology improvements might be possible. One farmer expressed this theme as:

> *"I'm already doing everything I can to save water and yet I keep getting asked to buy some new technology or do something different with how I water my crops."*

***Worry toward losing water rights***: Farmers were also concerned with water license erosion and loss of beneficial use. One farmer expressed a concern for securing water to leave their farm to their children.

> *"I have 25 acres I could farm but it's already difficult enough to farm 15 acres. I pay licenses for all 25 but what happens if we run out of water when I'm not farming the other 10? Will someone take it back or will the water be there for my children?"*

***Concerns over increasing water rates to pay for residential water use***: Many farmers residing in irrigation districts expressed a concern that their water rates would continue to rise to pay for more and more residential water uses. However, despite these concerns most farmers were willing to fund infrastructure provided that residential outdoor irrigation be managed. Given the findings from the residential survey indicating that residents would be willing to accept outdoor irrigation restrictions (see Figure 19 in the 2012 Okanagan Water Study: *Resident Descriptive Statistics report)* it is likely that growth could be managed in irrigation districts.

***Resistance to irrigation scheduling and technology changes***: Results from focus group surveys highlighted the diverse nature of the Okanagan agricultural community. With crops ranging from Christmas trees to cherries, irrigation technologies were as equally diverse. Farmers were resistant toward changing irrigation technologies unless they were considering changing crops. One farmer expressed this concern as:

> *"I'm happy with how my crops are growing with what I use now, I can't trust that if I change anything I'll do as well" and "I can't afford to put in a new irrigation system unless I'm replanting."*

Another farmer expressed their views as:

> *"If they [water managers] want farmers to change their irrigation systems there needs to be an incentive as most farmers can not afford new irrigation systems but I am sure they [farmers] would put them in if they [famers] could afford them."*

Farmers were also resistant to using irrigation schedulers. Although farmer concerns centred more on how the technology would isolate them from their crops rather than a distrust of the technology. One farmer expressed this theme as:

> *"I've tried a few ways to water crops including using the computer but I like to look [at the crops] and let them tell me how much water they need."*

***Water conservation vs. water efficiency***: Farmers often preferred to talk in terms of using water efficiently versus conserving water. For many, conserving water brought up questions about where and who gets the water they conserve. One farmer expressed a concern that saving water might also increase their risk of future crop failures.

> *"If I use less water one year then someone [referring to water managers] might tell me I don't need as much water next year. I don't waste water but I use what I've licensed so I have enough water for next season."*

Overcoming these types of concerns toward conserving water is crucial should the region desire to develop a holistic water management strategy that includes both residential and agricultural water use.

***Water trading***: At first, farmers were hesitant to consider water trading as a means to manage water shortages. However, in-depth discussions revealed a long history of informal trade agreements between farmers. Many farmers shared stories of working together to reduce water use and trade water so that all could harvest a portion of their crops, if at all possible. One farmer shared:

> *"I have priority on the stream but the last time there was a drought I was asked by [name withheld] upstream to cut back on watering so he could pull water from the stream to so he could harvest. I cut back and we worked out a deal to share the receipts."*

The long history of informal water trading may suggest a strong trust between farmers to work out an agreement but a desire to develop an agreement free from political interference.

***Concerns over political priorities***: Many farmers expressed a worry that regional priorities tended toward urban land development interests over agricultural resources. One farmer expressed this as:

> *"I'm not sure I'll pass on my farm to my children or sell the land. It's not ALR [Agricultural land reserve] land so I don't think the city wants it to stay a farm. So why stay if no-one wants a farm here."*

Contrasting this concern are findings from the residential survey that suggests residents are quite willing to self regulate and accept outdoor irrigation restrictions in order to protect agricultural land.

**Management Alternatives:**

The results of the workshops, surveys, and one-on-one interviews revealed a complex emotional and political landscape that suggests a variety of management strategies to improve water use efficiency and water shortage planning. The project reviewed numerous water management alternatives with residential and agricultural stakeholders. Alternatives evaluated included items such as changes in watering frequencies, reduction in urban water use, changes in the appearance of the urban environment, irrigation scheduling support, rebates on water efficient technologies and the introduction of water budgets. Each alternative fit within three larger themes:

- Policies toward adoption of water efficient irrigation technologies;
- Policies that affect crop selection and subsequent water usage;
- Policies that promote efficient water management practices within an agricultural water reserve

While important, themes 1 and 2 provided too difficult to examine due to the number of variations of questionnaires needed to accommodate the diversity of farms in the Okanagan. Subsequent farmer focus groups and stakeholder meetings assisted the research team in identifying the key priority for the region:

- Policies that promote efficient water management practices within an agricultural water reserve

The proposed BC provincial policy of supporting an agricultural water reserve provides an opportunity to secure water futures but does not address the issues of identifying when would the agricultural community exercise good water management practices under an agricultural water reserve nor how would farmers manage their water use through drought conditions. Implementing an agricultural water reserve could both remove barriers to water conservation and create new incentives for farm water use efficiency. And understanding under what conditions farmers would voluntarily choose to improve their farm's water use efficiency vs. rely upon adequate allocations has the potential to inform future allocation policies. Especially under drought conditions where seasonal water availability may not be sufficient to fulfil the commitments of the water reserve and meet the needs of non-agricultural uses.

To investigate the above issues, the research team identified two questions to explore in a subsequent farmer survey.

1. How would farmer choose to balance investments in improving their farm's water use efficiency against paying increased water rates/taxes to invest in additional storage
2. Under what various AWR drought responses would farmers change their water use behaviours

The structure for this investigation is discussed in section 2 of this report.

**Related Resident Findings:**

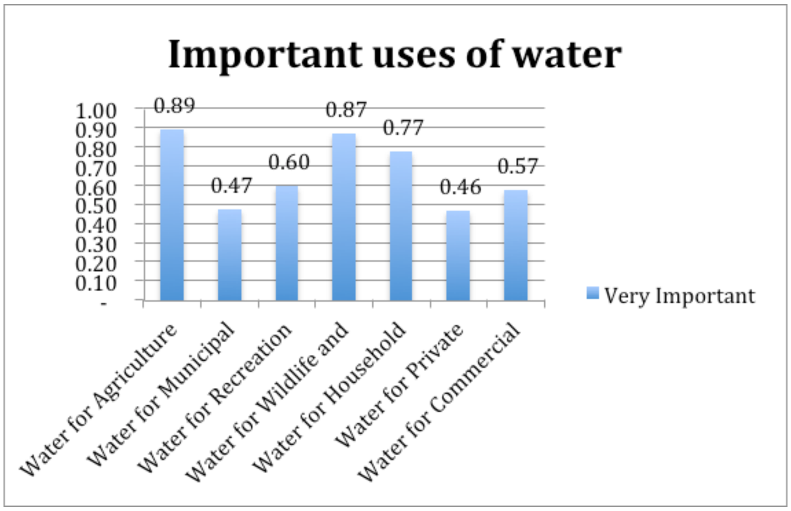
The resident and farmer survey both contain numerous attitudinal questions on climate change, water use, drought management and policy, and important water uses. Some agriculturally related residential study results are presented below.

**Water use and information sources:**

- About half of respondents indicated that they believe "water used by residents" (55.5%), "water used by business" (41.3%), and "water used by golf courses" (45.5%) have increased in the Okanagan over the last 10 years. Whereas 35.3% of respondents feel that the "water available for the natural environment" has decreased over the last 10 years. Only 34.3 % of respondents felt water used by agriculture has increased and 17.6 % of respondents felt water used by agriculture has decreased.
- A large portion of respondents (19.6% "strongly agree" and 59.8% "agree") believes that "water conservation programs should include options for changing water users' behaviour." Most respondents "agree" (59.8%) or "strongly agree" (19.6%) that "water conservation is an issue I am personally concerned about."
- Indicating possible support of mandated water restrictions, over half of respondents "<u>disagree</u>" (39.3%) or "strongly <u>disagree</u>" (13.4%) with the statement "water restrictions should be voluntary rather than mandated by the government"
- Respondents were willing to reduce their personal water use by an average of 44.2% during times of severe water scarcity, with a preference toward reducing the use of a dishwasher and lawn watering. Not surprisingly, reducing water for personal care (clothes washing, flushing toilets, and showering and bathing) was less preferred.
- However, over half of the respondents "agree" (11.7%) or "strongly agree" (46.3%) that "public money should be used to develop or acquire new water resources."

**On climate and specific management/policy options:**

- The majority of respondents (64.9%) believe that climate change is occurring presently.
- Half of respondents (51.5%) believe that "the severity of winters has <u>decreased</u>" and (38.6%) believe that "the frequency of water shortages has <u>increased</u>" in the Okanagan.
- More than 2/3rds of respondents find "restricting the amount of water that can be used on private lawns and landscapes" and "restricting the amount of water than can be used on public landscapes" to be <u>acceptable</u>
- Conversely, respondents indicated that "temporarily paying farmers to reduce production," "allowing local lakes and reservoirs to drain," and "reducing the amount of water available for wildlife and fish habitat" to be <u>unacceptable</u>.
- While most respondents (>80%) indicated they were personally concerned with water use, a large portion of respondents (>47%) indicated that they would find "brown" public green spaces "disturbing" and a larger portion of respondents (>51%) indicated that they would find "brown" private green spaces "disturbing." This may indicate that residents are more accepting of "brown" public spaces than "brown" private spaces.
- The majority of respondents indicated that "water for agriculture," "water for wildlife and the natural environment," and "water for household indoor use" are <u>important</u> for the Okanagan in times of water scarcity. If the responses are normalized from 0 to 1 (with 1 being the most important), respondents indicated that <u>agriculture was most important</u>, even over water for household uses (see below graph).




**Overall Outcomes:**

Through examination of the various alternatives for water conservation policy and implementation strategies, this study informs water management policy development by providing water management decision makers with a key list of priorities and considerations. This study reveals that farmers seek security to pass farms to a new generation of farmers provided that water is secure for the future. This study also revealed that prioritizing how agricultural water reserves would be developed might provide a significant incentive for additional water efficiencies and further water savings if farmers were recognized for their efforts to conserve water and bank water savings in the reserve. Further, it was revealed that farmers are very willing to work out trade agreements according to what works best in each region. Each and all of these themes are being explored and will be reported on in a supplemental study concluding the June 2013.

## 2. Methodology

This section outlines the project's approach to determine farmer preferences for water use and climate adaptation policies, and understand how respondents value various uses of water under possible climate change scenarios.

Project work occurred in two stages. Stage 1 – Develop policy scenarios for managing water demand and Stage 2 – Profile water user preferences. The following discusses the tasks involved in each stage.

***Stage 1a – Literature Review:***

The research team completed a focused review of water demand management and conservation literature, identifying the water management issues in the region and alternatives for addressing these issues. This review informed the development of a list of discussion points for Stage 1b. Further, the literature reviewed during this stage provided the foundation for developing study attributes during Stage 1c.

***Stage 1b – Interview decision-makers and stakeholders & Stage 1d – Consult with case study participants:***

Stages 1b and 1d are being reported together due to the close relationship of these two stages, the difference being the timing and context of each stakeholder contact. During stage 1b and stage 1d the research team conducted numerous interviews and workshops with members of the technical steering committee, the BC Fruit Growers Association, the public, and regional farmers to assess the acceptance and understanding of various management alternatives. Below is a subset of the various interviews and stakeholder workshops conducted.

- One-on-one interviews – Anna Warwick Sears & Nelson Jatel – OBWB
- One-on-one interviews – Ted Van der Gulik – BC Ministry of Agriculture
- One-on-one interviews – Neil Klassen – City of Kelowna
- One-on-one interviews – Denise Neilsen – Agriculture and Agri-Food Canada
- One-on-one interviews – Denise MacDonald – BC Fruit Growers Association
- One-on-one interviews – Toby Pike – South East Kelowna Irrigation District
- One-on-one interviews – Glen Lucas – BC Fruit Growers Association
- Workshop – Technical Steering Committee Members – Kelowna, BC September 22, 2011
- Workshop – Technical Steering Committee Members – Kelowna, BC November 25, 2011
- Workshop – Farmer focus group, BC Fruit Growers Association – Kelowna, BC January 17, 2012
- Workshop – Two resident focus groups, Kelowna, BC February 18, 2012
- One-on-one resident interviews – February and March, 2012
- One-on-one resident testing interviews – March, 2012
- Workshop – Technical Steering Committee Members – Webcast March 12, 2012
- One-on-one farmer survey testing & interviews – April, 2012
- Workshop – Farmer focus group – May 24, 2012
- Workshop – Technical Steering Committee Members – September 14, 2012
- Workshop – Technical Steering Committee Members -
- One-on-one farmer survey testing & interviews – July, 2012 – February, 2013

***Stage 1c – Compile concerns and alternatives:***

Key concerns and alternatives were compiled into a summary list of attributes for possible inclusion in the study questionnaires. Many options were eliminated from consideration at the November 25 2011 technical workshop and in subsequent focus group sessions with farmers. A subset of some of the alternatives considered for farmers is listed below:

- Crop watering frequency (change in the amount and or frequency of watering)
- Irrigation installation and management practices
- % of farmers educated on irrigation best practices
- Use of recycled and reclaimed water
- Irrigation scheduling support
- Rebates on irrigation technologies
- Improve water use information available to farmers
- Water budgeting per crop types
- Adaptive water licensing
- Organic soil application

***Stage 1e – Adapt key alternatives for application in a survey:***

Investigation from Stage 1c resulted in the three previously listed themes.

- Policies toward adoption of water efficient irrigation technologies;
- Policies that affect crop selection and subsequent water usage;
- Policies that promote efficient water management practices within an agricultural water reserve

Each option was evaluated to determine: 1) do farmers understand the policy options and can they make realistic decisions, 2) how applicable is the policy option to a wide variety of farmers, and 3) how relevant will the results be within the current policy environment and will the results provide information that can be integrated with the existing agricultural water demand model.

In developing the project questionnaires the research team solicited feedback from the technical committee and tested the list of alternatives developed in Stage 1c with various residential and farmer focus groups. Significant changes to the initial list resulted from this process, highlighting the importance of thorough testing.

For instance, one focus group session on May 24 2012 indicated that option 1 (irrigation technology policies) is very crop specific and would require numerous variations to accommodate a wide variety of farmers. Further, many farmers indicated that their decision to change or switch to a more water-efficient irrigation technology would depend on the crop they planned to grow in the future. Few indicated they would consider changing irrigation methods with their current crop and those that would consider it would only do so if they found their current irrigation system ineffective. Farmers did, however, indicate a desire to use water more efficiently, provided water savings would remain in the sector and they could afford the technology.

The investigation of each of the three alternatives revealed key themes that were presented in section 1 as well as insight into future investigations. The priority of which is:

- Policies that promote efficient water management practices within an agricultural water reserve

***Stage 2a – Design the discrete choice experiment and supplemental survey instrument:***

The research team presented an irrigation focused choice experiment to farmers during a January 17, 2012 focus group. Observations from this focus group revealed that while farmers understood and could complete the draft survey, additional investigation into the trade-offs between irrigation practices and land use choices would benefit the project.

The research team then prepared additional variations of the choice experiment and survey to farmers and farmer groups, as noted in Stage 1b. Each session improved the focus and clarity of the study questionnaires.

Based on analysis of residential data, it was determined that the two methods being considered (a discrete choice and continuous choice experiment) do provide substantive quantitative information that can inform policymaking and management decisions while delivering sufficient quantifiable data for later integration in the Okanagan water supply and demand model.

Following the September 14, 2012 stakeholder meeting the research team prepared a questionnaire based on the following:

1. A discrete choice experiment that presents various AWR drought policy responses and measures farmer behaviours under each option

This experiment was added to the study survey and tested with farming groups. Further, while the focus area has been the Okanagan, this question supports a broader BC response.

***Stage 2b – Collect Data:***

To facilitate survey data collection, the research team custom-developed two web-based water survey sites: www.waterstudy.ca to host the residential survey and www.watersurvey.ca to host the farmer survey. Due to the need to develop two separate web surveys, web development time and costs were significantly higher than anticipated. However, the additional investment provided for a broader range of analysis and application. Moreover, other communities in the Okanagan can easily utilize the developed study sites to collect regionally specific data.

The opening screen of the residential survey is shown in Figure 1.

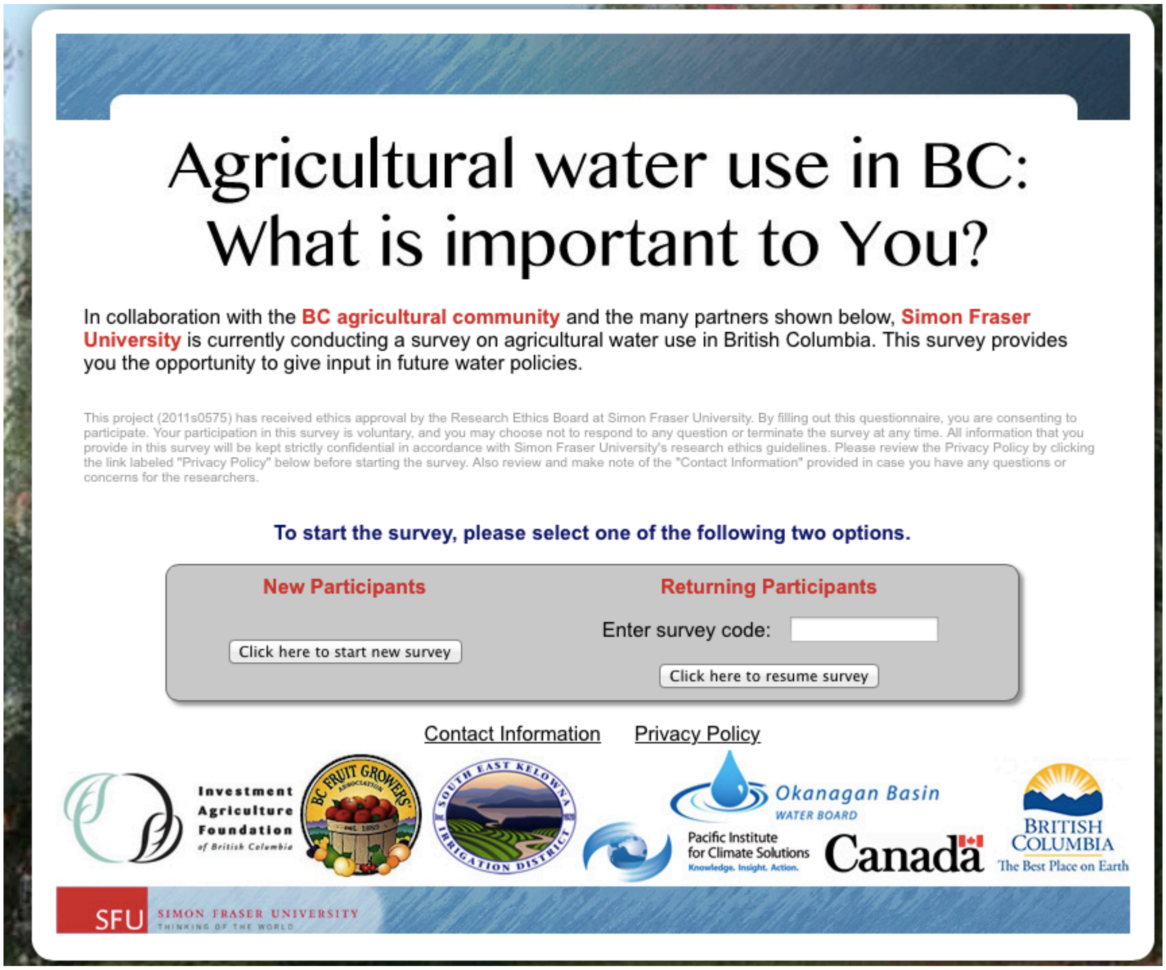



**Figure 1 – Internet Survey Opening Screen**

The BC agricultural survey website was extensively tested by the technical steering committee, Simon Fraser University water research group members, and select Kelowna, BC area farmers.

The research team with recruitment support by the South East Kelowna Irrigation District administered the on-line survey. Samples were drawn from a random selection of farmers in the South East Kelowna Irrigation District (Irrigation District) from contacts managed by the Irrigation District, and farms across the Okanagan as identified using spatial mapping in ArcGis Desktop 10.1. The resulting address list, including contacts managed by the South East Kelowna Irrigation District, provided contacts made between March 2013 and May 2013. The Irrigation District mailed an initial contact letter to its customers with information how to complete the online survey. The South East Kelowna Irrigation District subsequently mailed a follow up reminder postcard and letter at week 3 and week 7, respectively. The research team contacted farmers outside the South East Kelowna Irrigation District service area by post card initially and as a reminder.

***Stage 2c – Analysis and Reporting:***

Several reports are available documenting the results of this collaborative study. In addition to this report two key reports are available:

- Conrad, S. (2012). Assessing the effectiveness of climate change adaptation policies: a survey of residential preferences. Ottawa, ON. Natural Resources Canada.
- Conrad, S. (2012). Okanagan Water Study: Resident Descriptive Statistics. Simon Fraser University.

## 3. Detailed Data Results

The following section summarizes the results of the study, presented in the same order as the questionnaire. A final sample size of 224 was used in the analysis of results. A number of statistical methods were used to analyze the data. IBM SPSS Statistics 19 was used to analyze the descriptive elements of the survey, including sample frequencies, water use behaviour and attitudes (SPSS Incorporated, 2010).

***For how many years have you been farming?***

**Table 1 - Years spent farming**

| | Mean | Median | Mode |
|---|---|---|---|
| Years Farming | 22.59 | 20.00 | 10 |

***For how many years have you been farming in the Thompson-Okanagan region?***

**Table 2. Years spent farming in the Okanagan**

| | Mean | Median | Mode |
|---|---|---|---|
| Years Farming | 23.35 | 19.00 | 10 |

***For how many years do you plan to continue farming in the Thompson-Okanagan region?***

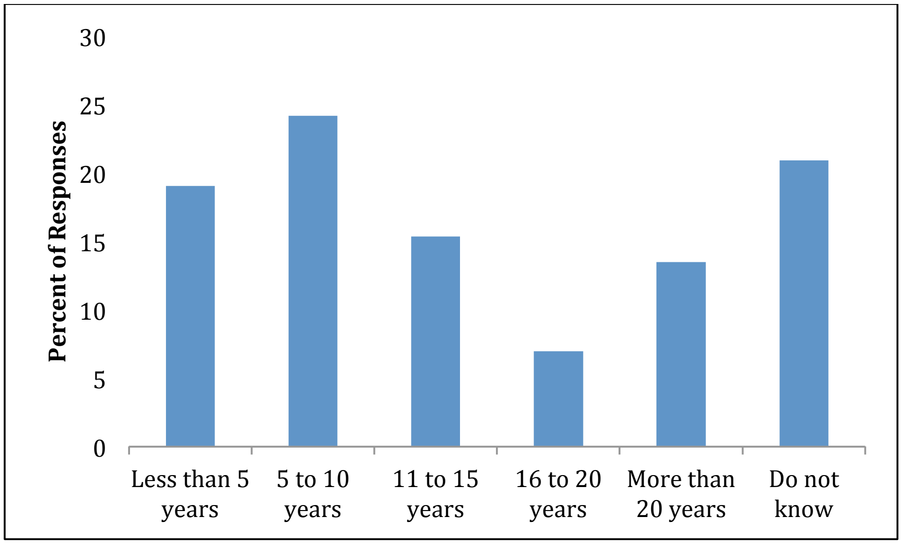



**Figure 2. Years expected to continue farming in the Thompson-Okanagan**

**Table 3. Years expected to continue farming in the Thompson-Okanagan**

| | **Frequency (%) (N=224)** |
|---|---|
| Less than 5 years | 19.1 |
| 5 to 10 years | 24.2 |
| 11 to 15 years | 15.3 |
| 16 to 20 years | 7.0 |
| More than 20 years | 13.5 |
| Do not know | 20.9 |

*What will likely happen to your farm after you stop farming?*

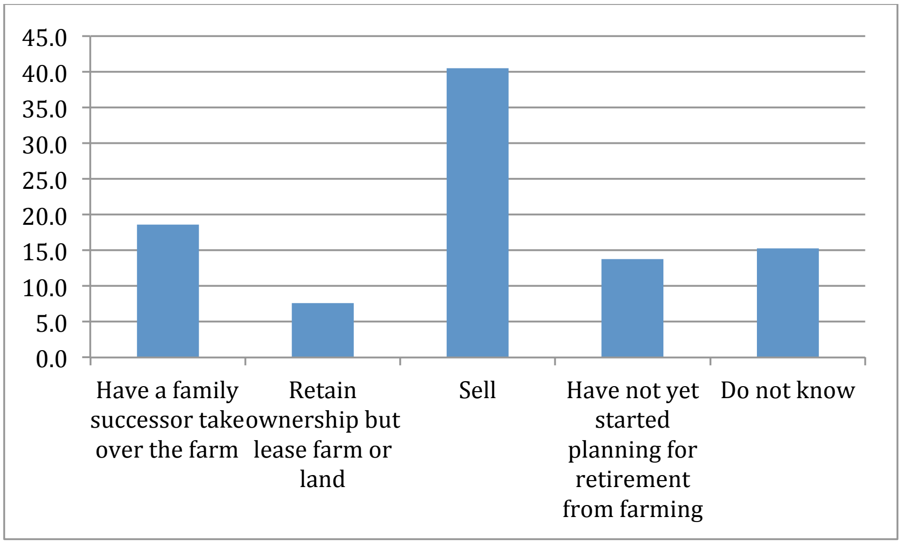



**Figure 3. Plans for farm after respondent stops farming.**

*What types of crops do you farm?*

**Table 4. Percentage of crops grown**

| | Mean Total Acreage (acres) |
|---|---|
| Forage | 38.17 |
| Orchard | 25.89 |
| Vineyard | 30.18 |
| Vegetable | 53.50 |
| Greenhouse | 0.50 |
| Ranch | 27.54 |
| Perennial | 14.40 |
| Annual | 65.75 |
| Tree | 4.80 |

***Do you own or lease other non-irrigated land or non-utilized irrigation licenses?***

**Table 5. Total non-utilized irrigation licenses**

| | **Mean Total Acreage (acres)** |
|---|---|
| Other non-irrigated marginal land | 67.38 |
| Other non-arable land | 91.90 |
| Other non-utilized irrigation licenses | 1.00 |

***What are your intentions for your farm in the next 5 years?***

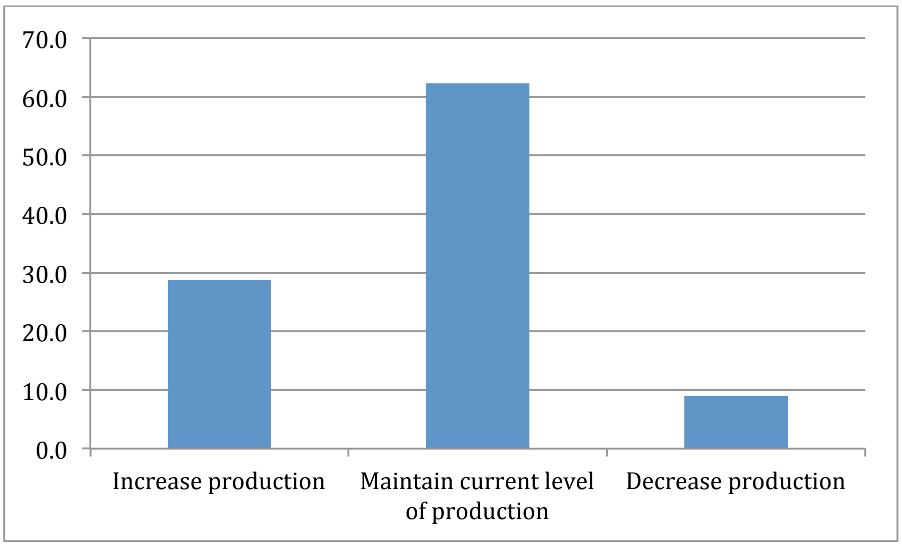



**Figure 4. Farm intentions for the next 5 years**

**Table 6. Farm intentions for the next 5 years**

| | **Frequency (%) (N=224)** |
|---|---|
| Increase production | 28.8 |
| Maintain current level of production | 62.3 |
| Decrease production | 9.0 |

*What is your farm's primary source of irrigation water?*

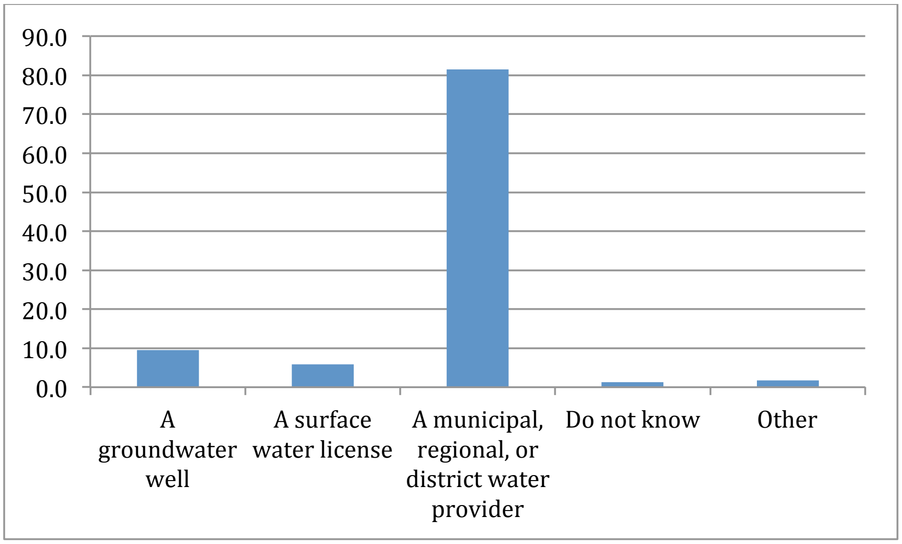



**Figure 5. Primary sources of irrigation water**

**Table 7. Primary sources of irrigation water**

| | **Frequency (%) (N=222)** |
|---|---|
| A groundwater well | 9.5 |
| A surface water license | 5.9 |
| A municipal, regional, or district water provider | 81.5 |
| Do not know | 1.4 |
| Other | 1.8 |

***How often have you experienced any water shortages on your farm in the last 10 years?***

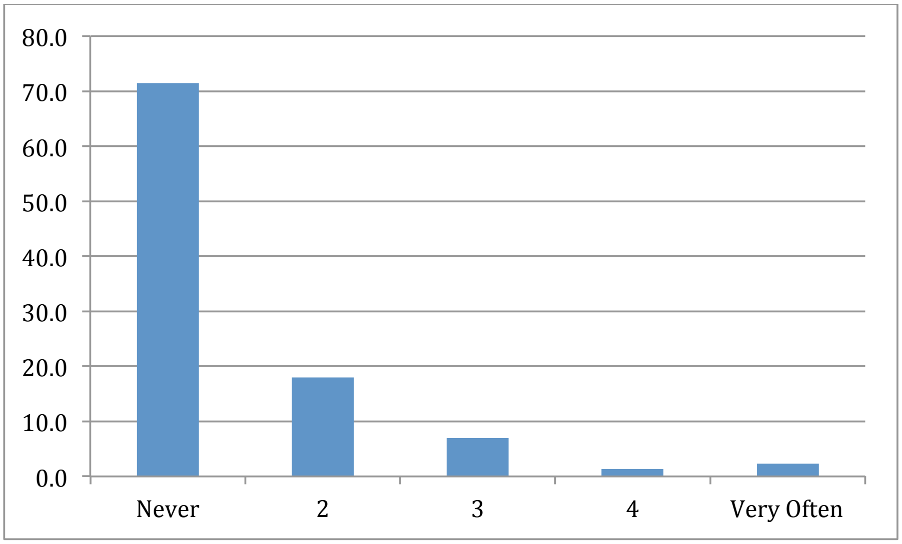



**Figure 6. Frequency of water shortages in the last 10 years**

**Table 8. Frequency of water shortages in the last 10 years**

| | **Frequency (%) (N=217)** |
|---|---|
| Never | 71.4 |
| 2 | 18.0 |
| 3 | 6.9 |
| 4 | 1.4 |
| Very Often | 2.3 |

***If you have experienced water shortages, to what extent were the water shortages caused by any of the following issues?***

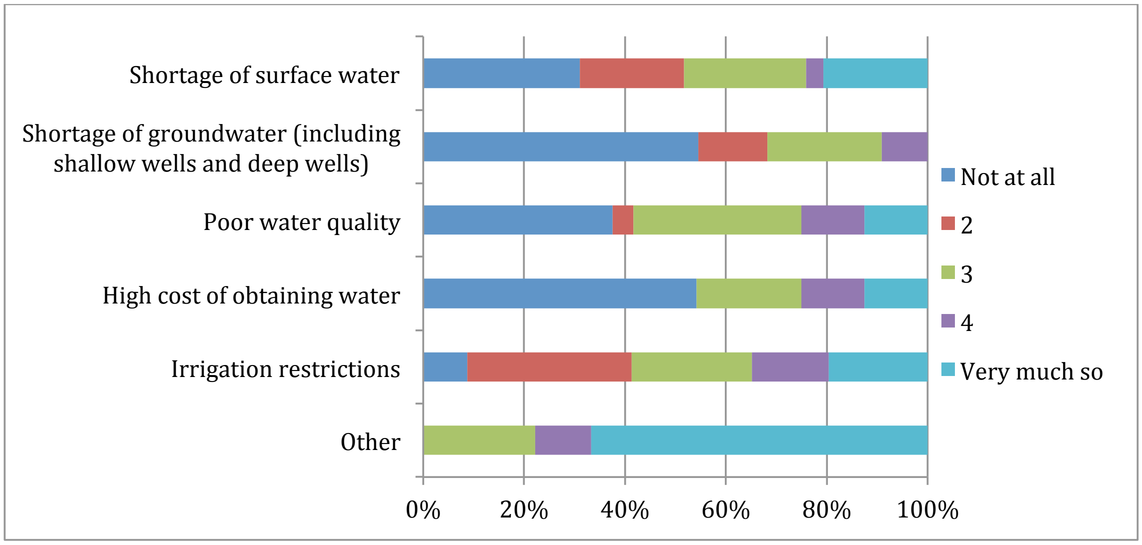



**Figure 7. Extent of issues causing water shortages**

***What license priority do you believe you have on your primary source of irrigation water? (Surface water users only)***

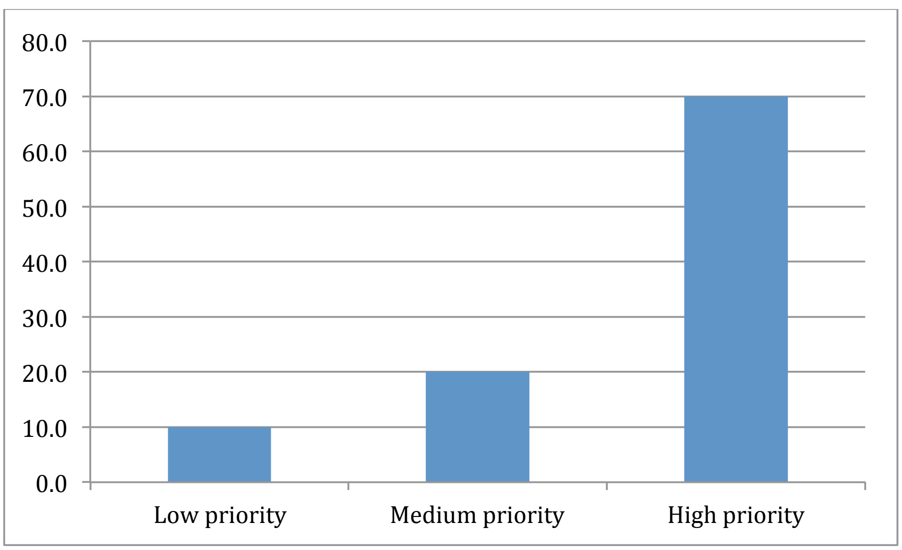



**Figure 8. Belief of existing license priority**

***Do you have a license to store water in support of your primary source of irrigation water?***

**Table 9. Proportion of surface water licensees with storage licenses**

| | Frequency (%) (N=193) |
|---|---|
| **Yes** | 12.9 |
| **No** | 87.1 |

***Would you be comfortable reporting the water you withdraw from your primary source of irrigation water?***

**Table 10. Proportion of farmers comfortable reporting water use**

| | Frequency (%) (N=194) |
|---|---|
| **Yes** | 63.3 |
| **No** | 36.7 |

***How much do you agree or disagree with each of the following statements about managing the Thompson-Okanagan region's water resources?***

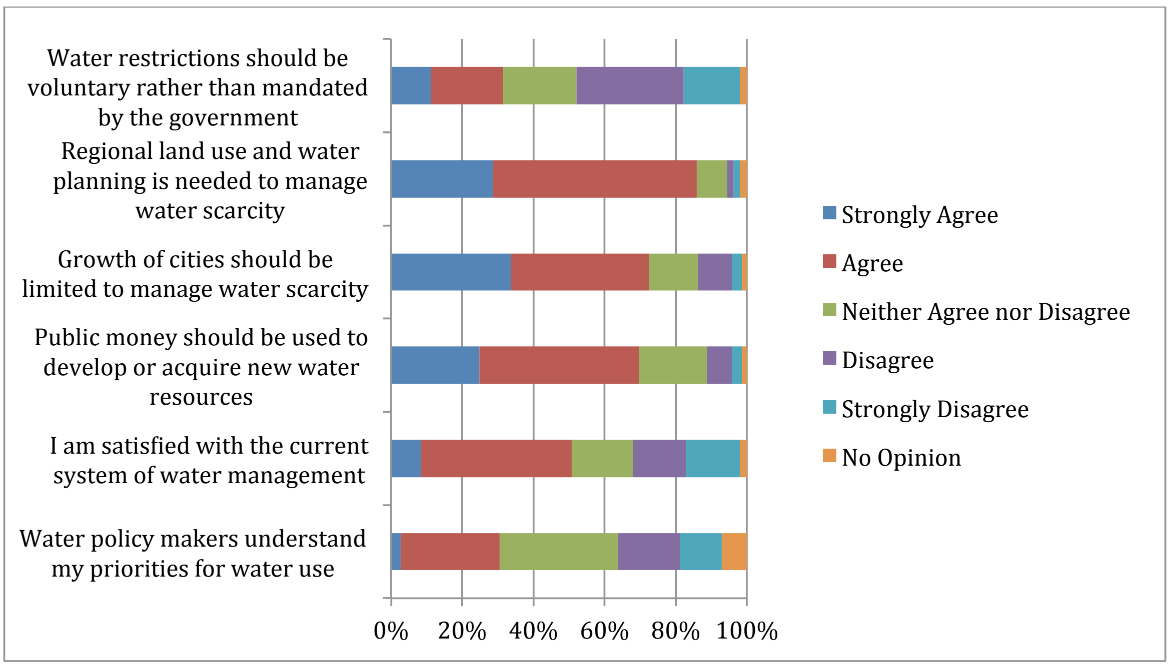



**Figure 9. Agreement with statements about water management practices**

*How much do you agree or disagree with each of the following statements about water licensing?*

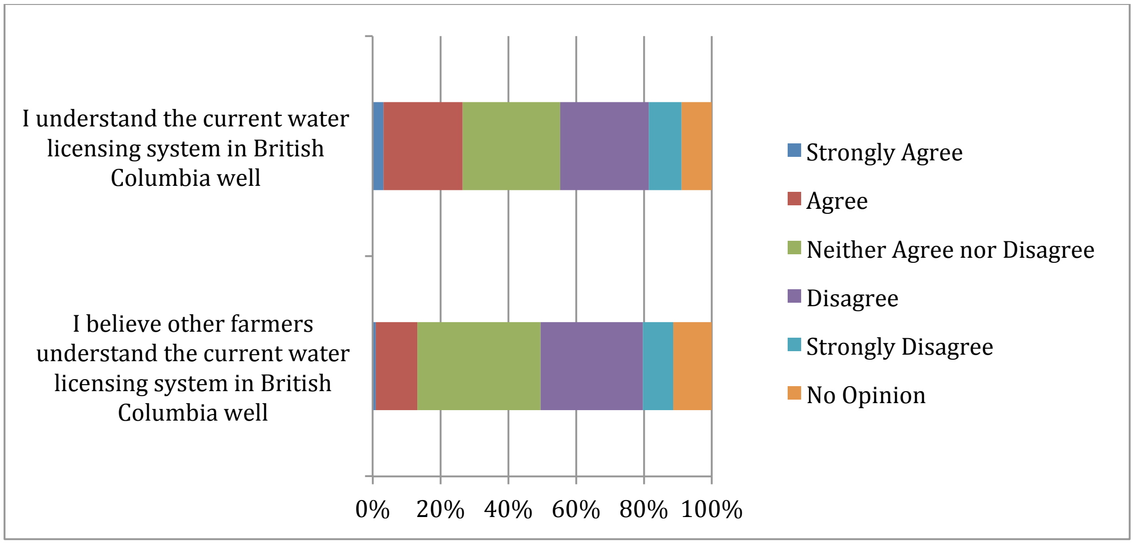



**Figure 10. Agreement with statements about water licensing**

*Do you support the development of an agricultural water reserve in British Columbia?*

**Table 11. Support by farmers for an agricultural water reserve in British Columbia**

| | Frequency (%) (N=212) |
|---|---|
| **Yes** | 89.2 |
| **No** | 10.8 |

***How much do you agree or disagree with the following statement about establishing an agricultural water reserve?***

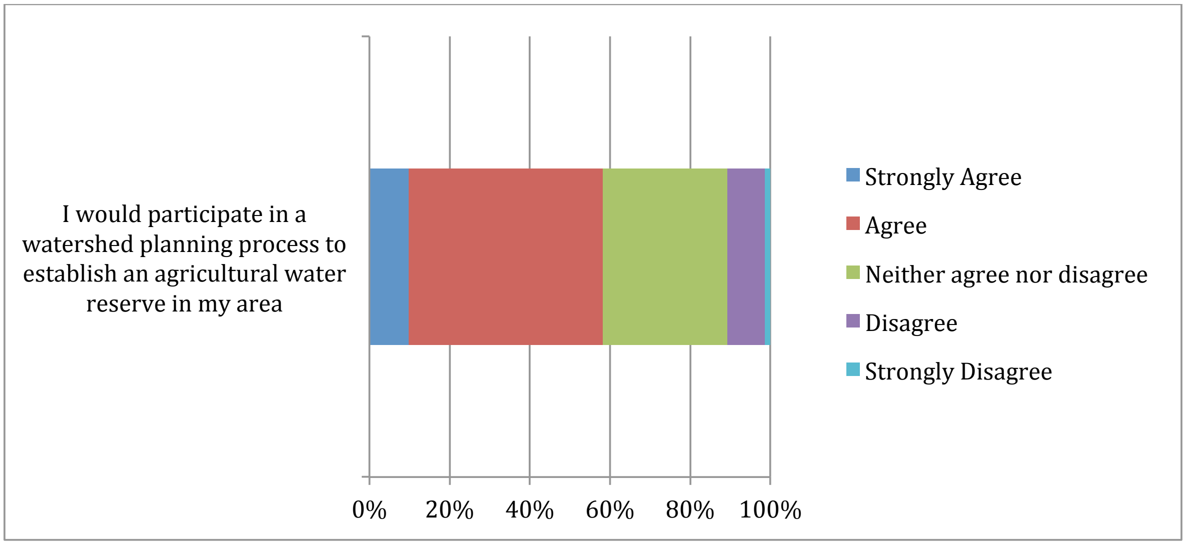



**Figure 11. Support for participating in a watershed planning process**

***If an agricultural water reserve was established in the Thompson-Okanagan region, how likely would you be to…***

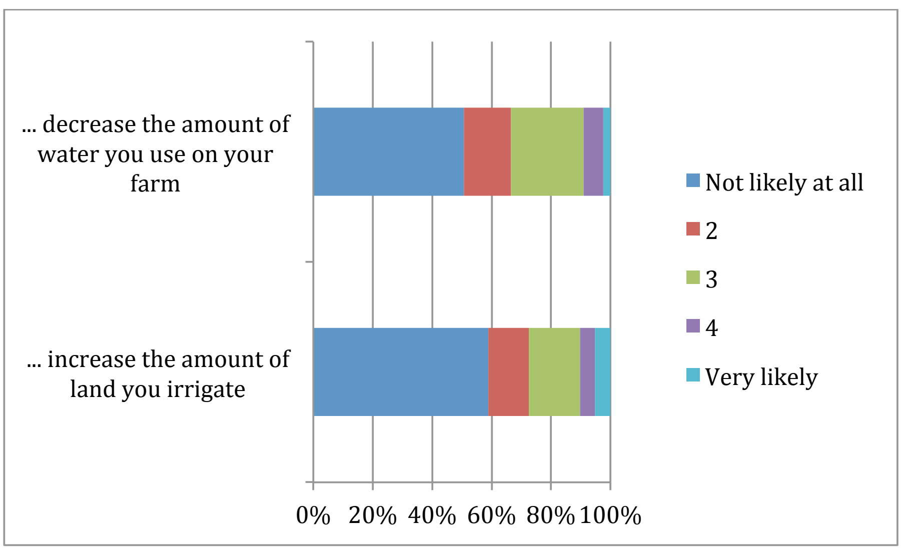



**Figure 12. Likelihood of farmers modifying production under an agricultural water reserve**

***Which of the following statements most accurately reflects your opinion about climate change in the Thompson-Okanagan region?***

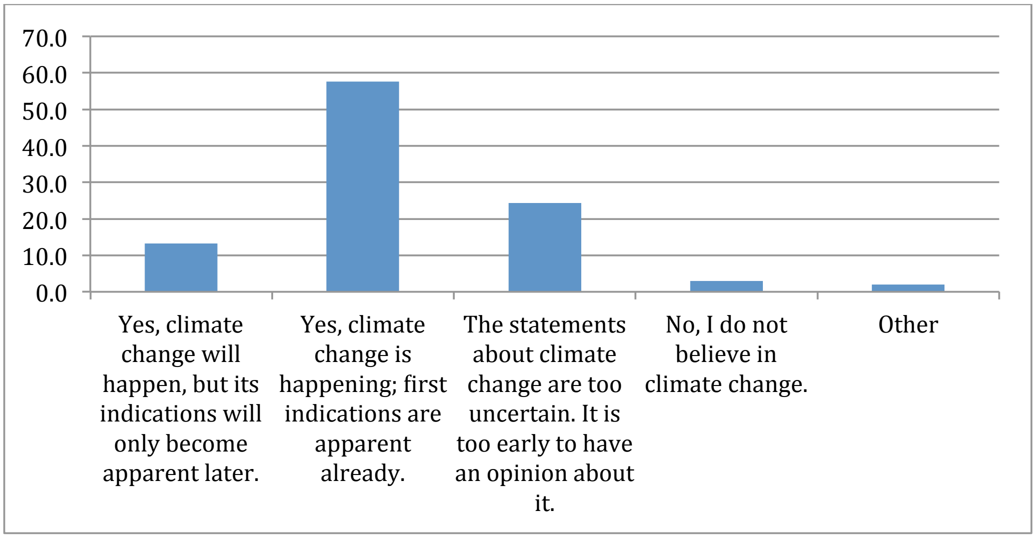



**Figure 13. Farmer opinions about climate change**

***Have you noticed any changes to the following items in the Thompson-Okanagan region?***

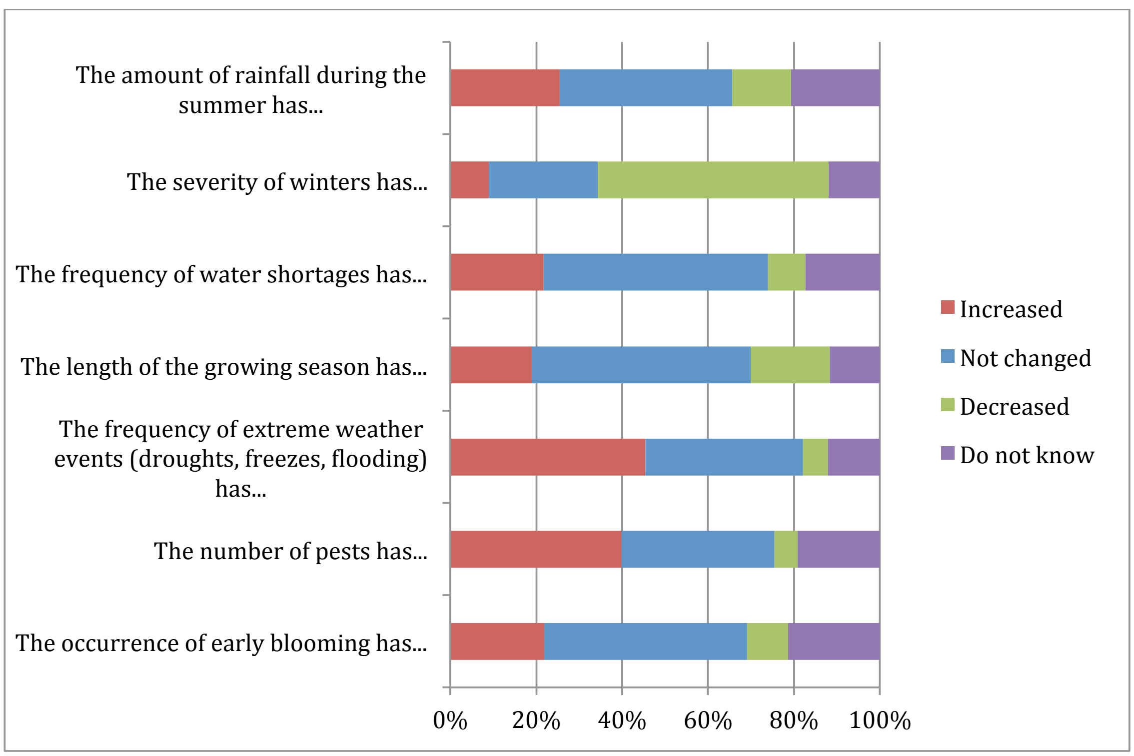



**Figure 14. Farmer perception of changes due to climate change**

***To reduce the impact from water shortages, how acceptable would each of the following management responses be to you?***

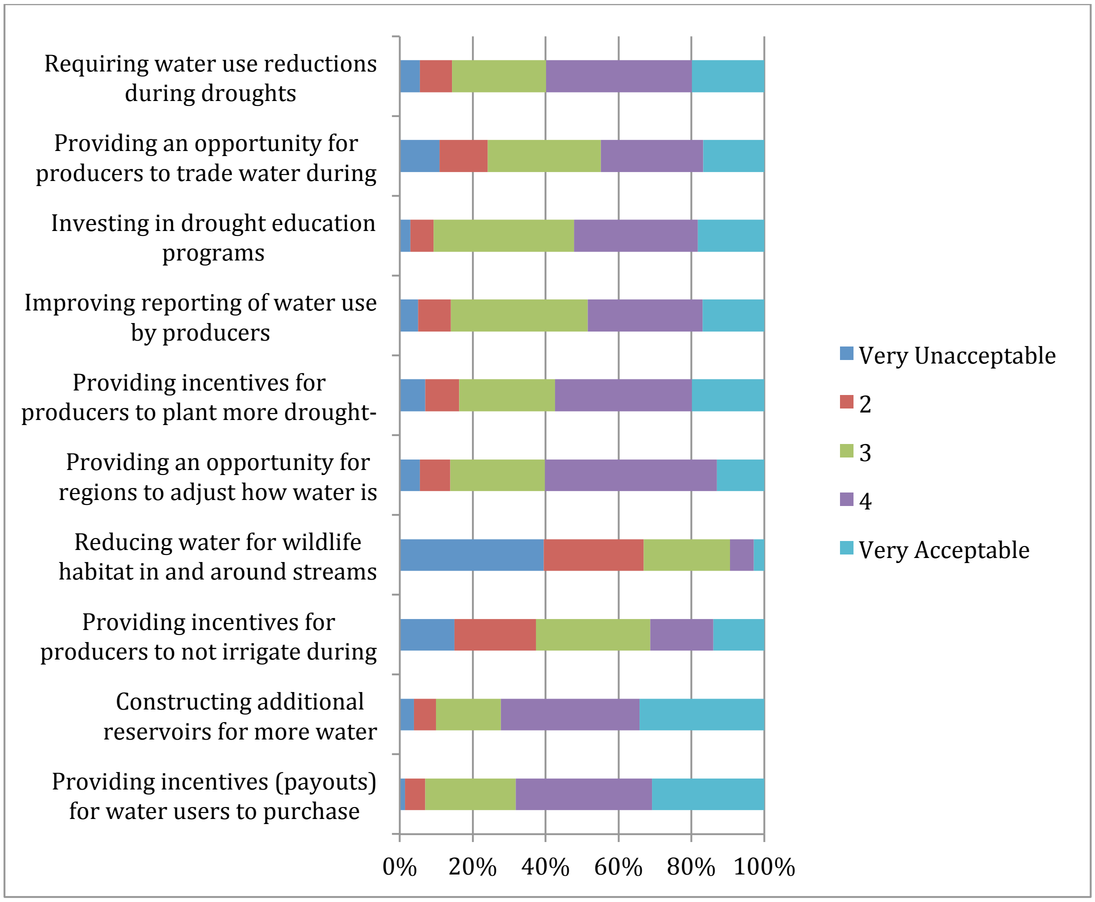



**Figure 15. Farmer acceptance of management responses to water shortages**

***What is the ownership status of the land where your farm is located?***

**Table 12. Ownership status of farmed land**

| | Frequency (%) | N |
|---|---|---|
| **Land that is leased or rented** | 12.1 | 27 |
| **Land that is owned by the produce** | 78.6 | 176 |
| **Land owned by the Crown** | 0.9 | 2 |
| **Other** | 2.2 | |

***What is your relationship to the farm?***


**Figure 16. Respondent relationship to farm**

**Table 13. Respondent relationship to farm**

| | **Frequency (%) (N=224)** |
|---|---|
| I am an owner/lessee of the farm | 87.8 |
| I am an employee of the farm | 4.3 |
| I am family member to the farmer | 5.3 |
| Other | 2.7 |

*What percentage of your total income comes from on-farm sources?*

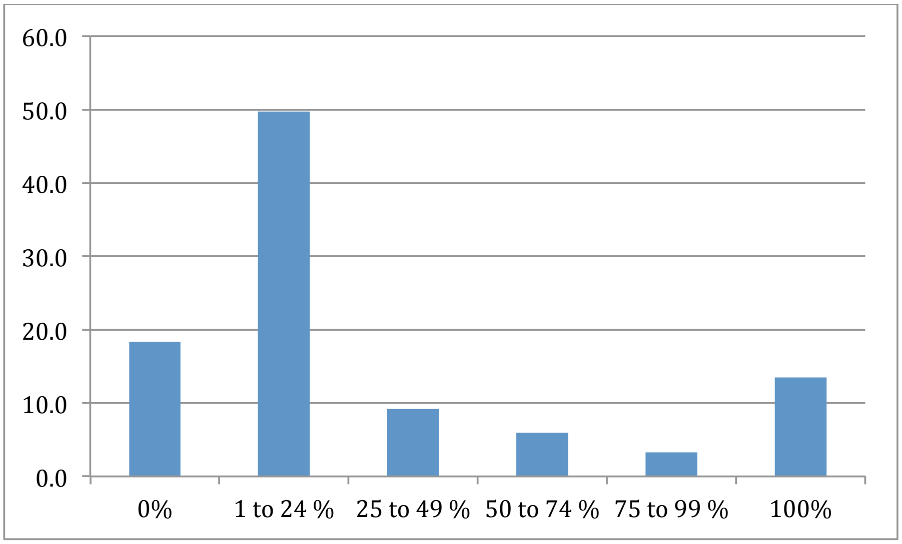



**Figure 17. Percentage of total income earned from on-farm sources**

**Table 14. Percentage of total income from on-farm sources**

| | **Frequency (%) (N=224)** |
|---|---|
| 0% | 18.4 |
| 1 to 24 % | 49.7 |
| 25 to 49 % | 9.2 |
| 50 to 74 % | 5.9 |
| 75 to 99 % | 3.2 |
| 100% | 13.5 |

*Which of the following age categories describes you?*

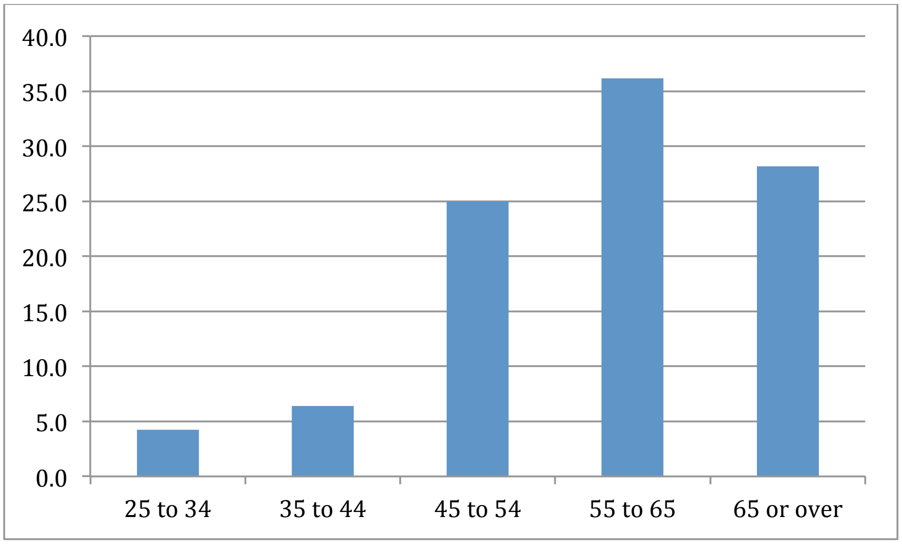



**Figure 18. Respondent age categories**

**Table 15. Respondent age categories**

| | **Frequency (%) (N=224)** |
|---|---|
| 25 to 34 | 4.3 |
| 35 to 44 | 6.4 |
| 45 to 54 | 25.0 |
| 55 to 65 | 36.2 |
| 65 or over | 28.2 |

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