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Evaluation of Community Preferences for Decentralised Water Management Systems: A Case Study in Akaroa, Banks Peninsula

A thesis
submitted in partial fulfilment
of the requirements for the Degree of
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Han Sun

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Evaluation of Community Preferences for Decentralised Water Management Systems: A Case Study in Akaroa, Banks Peninsula

by

Han Sun

Limitations on the supply of fresh water and increasing demand for council supplied water have become major issues in Akaroa, a tourist town on the Banks Peninsula approximately 80 kilometres from Christchurch City. Restrictions on domestic water use in the summer and new requirements for decentralised water management systems for new construction have been used to alleviate the burden of town water supply. Rainwater harvesting systems (RWHS) and greywater reuse system (GWRS) both represent potential options to decentralise the current water supply even further. This study informs the ongoing debate about water allocation on the Banks Peninsula by conducting a choice experiment (CE) to evaluate Akaroa homeowners' preferences for installing these systems. Primary data was collected from Akaroa residents, and a latent class model was specified to estimate willingness to pay (WTP) for decentralised water supply systems. Results reveal that approximately two-thirds of the sample actually had a negative WTP for decentralised systems (range from -$3,145 to -$1,672), while WTP estimates for the remaining respondents ranged from $1,912 to $2,749. For both of these groups, subsidies will be required to encourage the adoption of all types of systems. Identification of the factors that affect latent class membership could be a focus for further studies.

Keywords: Choice modelling, Willingness to pay, Rainwater, Greywater, Policy, Banks Peninsula

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ABIC- adjusted Bayesian Information Criterion,

AIC- Akaike's Information Criterion,

ASC- alternative specified constant,

BIC- Bayesian Information Criterion,

CAIC- Bozdogan's consistent Akaike's Information Criterion,

CE- choice experiment,

ECM- error components logit model,

GWRS- greywater reuse system,

IC- information criteria,

LC- latent class,

MNL- multinomial logit,

RP- revealed preference,

RPM- random parameter model,

RUT- random utility theory,

RWHS- rainwater harvesting system,

SMNL- scaled multinomial logit,

SP- stated preference,

WTP- willingness to pay,

Chapter 1

Introduction

Water resources are becoming increasingly scarce globally, including New Zealand. So planning for various water sources is a high priority for domestic water management. Population increases boost total water consumption while new water supply options are often too costly or altogether unavailable. For example, in Banks Peninsula, the existing water resource is limited due to the nature of the local climate and landscape. The demand of water seasonally exceeds the capability of designed municipal water supply due to summer visitors. This situation can result in stringent water use requirements in new construction applications (Christchurch City Council, 2014), and existing households. Also, there is an increasing recognition of the water, energy, operation, and maintenance savings that can be realised through the implementation of water-saving or decentralising initiatives. This study applies an economic approach to evaluate proposed decentralised water management systems, and therefore provides some useful information for water managers in terms of conducting the budgets.

Decentralised water management systems are defined as independent water supply and storage systems that spread across a certain area. Typically these systems are installed in end users' properties. Decentralised water management systems include rainwater harvesting and greywater reuse that provide water additional to the reticulated water supply. The end uses of the water collected from decentralised water management systems are predominantely non-potable (e.g. gardening, toilet flushing).

Numerous studies describe the potential of decentralised water management systems for water conservation in domestic housing. Particular attention in the literature has focused on rainwater harvesting systems (RWHS) (Domènech & Saurí, 2011; Friedler, 2008; Ghisi & Mengotti de Oliveira, 2007; Z. Li, Boyle, & Reynolds, 2010; Morales-Pinzón, Rieradevall, Gasol, & Gabarrell, 2015; Mwenge Kahinda & Taigbenu, 2011; Villarreal & Dixon, 2005). However, it is rare to see studies that focus on the value of utilising decentralised water management systems in residential housing, and how feasible it is to adopt those systems at a household level (Tapsuwan, Burton, Mankad, Tucker, & Greenhill, 2014). Studies from an economic aspect (Ahmed, Al Sidairi, Prathapar, and Al-Adawi (2008); Z. Li et al. (2010); Morales-Pinzón et al. (2015); Mwenge Kahinda and Taigbenu (2011)) are useful for understanding various aspects of the decision to adopt a domestic water management system. For example, Ahmed et al. (2008) suggest that greywater systems are financially and technically feasible to achieve certain social benefits. In Ireland, although RWHS and greywater reuse systems (GWRS) have enormous potential for the conservation of potable water, the cost of purchasing and installing these systems is a major obstacle for some Irish house owners (Z. Li et al., 2010). Estimation of homeowners' preferences for improved water efficiency devices can assist with determining better house designs, coping with water shortage, and achieving better water management.

There is a gap in the literature between the technical potential of designing decentralised water management systems and the value to residential homeowners for adopting these systems. The technical potentials of decentralised water management systems to contrinbute to water saving and financial saving have been widely discussed by researchers (Ahmed et al., 2008; Friedler, 2008; Ghisi & Mengotti de Oliveira, 2007; F. Li, Wichmann, & Otterpohl, 2009; Morales-Pinzón et al., 2015; Ni et al., 2012; Villarreal & Dixon, 2005). There is, however, little focus in the pre-existing studies investigate the values of decentralised water management systems from the residents' aspect. The adoption of decentralised water management systems, such as RWHS, in residential housing is very low in Christchurch. One of the impediments to mainstreaming ecologically sustainable housing designs is consumer resistance, based on perceptions of eco-housing as being less aesthetically pleasing, and less economically attractive for resale than traditional housing (Minnery, McFallan, Mead, & Fedrick, 2003). So financial and aesthetic considerations are two factors that can be expected to affect residents' behaviour, including their willingness to adopt decentralised water management systems.

It is crucial to understand the end-user behaviour towards decentralised water management systems as market demand is the primary driver of adopting water-saving devices (Chau, Tse, & Chung, 2010). To increase the adoption of decentralised water management systems and encourage people to conserve water, it is important to understand more about the extent to which people value decentralised water management systems. Willingness to pay (WTP) is the maximum amount of money that a customer will pay to buy a product. Accurate measurement and analysis of WTP for decentralised water management systems can improve understanding of the product and context-specific factors that influence the demand for such systems and how to increase their adoption through economic incentives (McIlwaine & Redwood, 2010; Tapsuwan et al., 2014).

There is sustainability risk for the reticulated water supply in Akaroa, a small town on Banks Peninsula, 75km east of metropolitan Christchurch. The local water supply is sourced from local streams and wells. Seasonally changed stream flow levels and long-term climate change create the sustainablility risk for the main water supply in this area. The Christchurch City Council manages the domestic water supply in Akaroa, and because of a limited potable water supply and seasonally fluctuating water demand, sometimes restricts water use in Akaroa. Particularly in summer, from November to January, the City Council water supply to Akaroa often is limited on one of four levels (see Appendix A). Reducing water usage, increasing water use efficiency, and recycling wastewater are some options for achieving better water management for the area. Since 1st December 2014, for all new premises constructed in Akaroa, a tank or facility with a minimum capacity of 5,000 litres is required for collecting and storing rainwater for non-potable purposes only (Christchurch City Council, 2014).

Incentive-based water-saving behaviour changes are an effective approach to water conservation (Yung, Shuk Man, & Wai Kin, 2014) because beneficial economic outcome is one of the main drivers of demand for water-saving devices. Estimating Akaroa house owners' WTP for those devices can identify preferences for the adoption of alternative water management systems, and identify whether there is a gap between the actual market prices of the decentralised water management systems and people's WTP, thereby indicating the economic incentives required to get people to adopt the devices in Akaroa.

Chapter 2

Literature Review

This review investigates the potential benefits of decentralised water management systems and describes the characteristics of RWHS and GWRS, which are the focus in this study. Literature that has evaluated decentralised water management systems is introduced.

2.1 Potentials of Domestic Water Management Options

2.1.1 Rainwater Harvesting System

RWHS can improve stormwater management, wastewater treatment, and appreciation of the water resource in urban environments (Ghisi & Mengotti de Oliveira, 2007; Kinkade-Levario, 2007; Villarreal & Dixon, 2005). Villarreal and Dixon (2005) investigated a RWHS for a large residential urban area in Ringdansen, Sweden. They found that rainwater harvesting resulted in a 30-60% reduction in the total amount of water supplied to residents. Villarreal and Dixon (2005) estimated that a RWHS in Ringdansen would supply almost 60% of the water needed for irrigation of the central area during the summer months. A study done in the United States by Lopes, Marques, Dornelles, and Medellin-Azuara (2017) also finds that RWHS has the potential for non-potable water conservation even under high demand and low rain collecting area. In the study area, they find a 5,000L tank is preferable regarding water saving which is at least 50% of the normal amount of non-potable water use (Lopes et al., 2017). Another study also finds similar results that show a positive impact of RWHS on water conservation. In a case study in Barcelona, more than 60% of the garden watering demand can be met with collected rainwater for both single and multi-family buildings (Domènech & Saurí, 2011).

According to Kinkade-Levario (2007, p. 32), a RWHS consists of six basic parts.

1. Catchment area: the surface to catch the rain. It is the roof of the residential houses.
2. Conveyance: channels or pipes that transport the water from catchment area to storage.
3. Roof washing: the systems that filter and remove contaminants and debris (e.g. first-flush devices).

4. Storage: water tanks that store the collected rainwater. There are three sizes of tanks (<5,000L, 5,000-25,000L, >25,000L) evaluated as attributes in the study by Tapsuwan et al. (2014).

5. Distribution: the system that delivers the rainwater, either by gravity or pump.

6. Purification: includes filtering equipment, distillation, and additives to settle, filter, and disinfect the collected rainwater. The purification is only required for potable water use.

2.1.2 Greywater Reuse System

The wastewater from kitchens, bathrooms and laundry is greywater, and it is distinct from black water that comes from toilets. Greywater does not have as high a health risk as black water, and it is suitable for domestic recycling and reuses for gardening purposes (Redwood, 2008). Greywater is widely used as a supplemental source of irrigation water, which can, therefore, conserve water supply (Ahmed et al., 2008; Friedler, 2008; F. Li et al., 2009; McIlwaine & Redwood, 2010). Reuse the greywater in the residential house could conserve 40% to 47% of normal water consumption (Almeida, Melo, Paula, Silva, & Rita, 2001, as cited in Santos, Taveira-Pinto, Cheng, & Leite, 2012). Redwood (2008) investigated a project featuring a 'four barrel treatment kit'. Four barrels are connected one after another in a line. The first barrel's function is to separate the solid and floating matters. The second and the third barrels then take mid-level water from the first barrel and treat it via an anaerobic method using bacteria established on the gravel in these two barrels. The water finally flows from the top of the third barrel to the fourth one, a storage barrel. With three days of retention, this system can supply sufficient irrigation water for 20-30 trees (e.g. olives, fruit), and the water quality is acceptable under 1989 WHO Guidelines (Redwood, 2008). Capital cost for this greywater system is 400-500 US dollars. Emitted odour and the cost are the potential obstacles to the adoption of this device (Redwood, 2008). Greywater systems reduced water bills in Cyprus and Jordan by 36% and 27% respectively. The water users' WTP for the system in Palestinian Territories is 35% of the capital cost of the greywater system (Redwood, 2008).

Tapsuwan et al. (2014) evaluate three types of greywater system: greywater diversion device, greywater treatment device (for outdoor use) and greywater treatment device (for indoor/outdoor use). The greywater diversion system is part of the plumbing system. This system redirects untreated greywater directly to the irrigation system. The treatment devices treat and store this water for use as needed, for purposes such as outdoor (lawn and garden) use and in some cases indoor (toilet and laundry) use (Tapsuwan et al., 2014). The installation of greywater systems contains plumbing to connect to the pre-existing household water network, which requires fittings such as connectors, pipes and bends for the plumbing work. A small storage tank will be needed for the treatment system.

2.2 Previous Studies Valued Rainwater Harvesting Systems and Greywater Reuse Systems

The majority of studies valued decentralised water management systems are conducted on the systems' economic viability using cost-benefit and life cycle analysis approaches (Karim, Bashar, & Imteaz, 2015; Morales-Pinzón et al., 2015; Ni et al., 2012; Rahman, Dbais, & Imteaz, 2010). These studies have narrowly focused on the financial factors that affect the adoption of the systems. They provide little information from the potential users' prospect for increasing the system adoption level. Only a small proportion of literature try to explore the factors other than actual costs of the systems that affect people's behaviour towards adopting decentralised water management systems (Tapsuwan et al., 2014). Demographical factors and attitude of the water users are found to be determinants of the adoption (Tapsuwan et al., 2014).

Tapsuwan et al. (2014) conducted a choice experiment (CE) study of decentralised water systems (i.e. RWHS, GWRS, and groundwater bores) in Australia. Specifically, the options in their study are bores, small, medium and large rainwater tanks, a greywater diversion device, and greywater treatment devices (outdoor and indoor/outdoor). The results show that 67% of participants would buy the greywater diversion device with no subsidy, which is the highest percentage among the decentralised water system options under investigation (all others were 17% or less). The subsidies required for lifting the adoption levels of decentralised water systems were estimated. The authors concluded that an AU$500 subsidy would be needed for full adoption of greywater diversion devices. For greywater treatment devices, one-off subsidies of AU$4,400 and AU$8,200 per household are required for the full adoption of indoor/outdoor and outdoor appliances, respectively. Sixty-three percent of the sample would require partial subsidies of $1,650, $2,650 and $4,950 to adopt RWHS with small (<5,000L), medium (5,000-25,000L) and large (>25,000L) tanks, respectively. For the rest of the sample (37%) to adopt these systems they would have to be free (Tapsuwan et al., 2014). This Australian have reassured the fact that the respondents are willing to pay less than the actual market price for the devices. However, it measures the difference between the respondents' value and the actual cost of the systems. The study also identifies that income and coping behaviour are the factors affecting the WTP.

The research done by Tapsuwan et al. (2014) provides useful information for the methodology of this study. The applied CE method can collect the data for estimating the WTP of the homeowners. The CE method can therefore be considered to use in this study. The content and structure of the questionnaire also can be adopted into the survey of this study.

Chapter 3
Research Questions and Objectives

3.1 Research Problem Statement

In Akaroa, public drinking water is provided by Christchurch City Council through a reticulated water supply system. Currently, the Akaroa water supply scheme takes water from four streams (Aylmers, Grehan, Balguerie and Takamatua) and two wells, one at Settlers Hill Road (138 metres deep) and one at Aylmers Valley (41 metres deep). A new water treatment plant at L'Aube Hill was built in 2015. Two main water reservoirs along with four small ones store and supply water for most properties in Akaroa by gravity (Christchurch City Council, 2016b).

The development and growth of townships on Banks Peninsula are constrained by the capacities of the public water supply and sewage disposal systems. According to Christchurch City Council acting manager Tim Joyce, in the summer, with large numbers of holiday home tenants and tourists coming into Akaroa, water consumption can double to an average of about 1 million litres a day, and often goes higher (Robinson, 2014). During peak demand in January, average water use could reach 1.5 million litres per day, and the maximum record in a day reached 2 million litres (Robinson, 2014). The water conflict in Akaroa occurs in the summer, particularly in January, at the time of lowest stream flow (water supply) concurrent with the highest population (water demand). The peak of discharged water also occurs in January (Christchurch City Council, 2016a).

The use of decentralised water management systems could play a critical role under current circumstances and in the foreseeable future. Collecting and utilising rainwater, for instance, could alleviate the potential burden of council water supply for this area. Moreover, the cost of upgrading and expanding the infrastructures would be saved if domestic water devices were widely adopted in Akaroa.

This research aims to estimate the WTP or incentives required (willingness to accept - WTA) for the adoption of decentralised water management systems in existing housing in Akaroa.

3.2 Research Objectives

In order to achieve the aim of this study, objectives are:

I. To investigate Akaroa residents’ perceptions of RWHS and GWRS.

II. To estimate residents' WTP for RWHS and GWRS.

III. To evaluate possible factors that affect people's decisions on choosing decentralised water management devices.

IV. To find out the gap between WTP and the actual market prices of decentralised water management devices.

V. To provide suggestions for potential incentives or regulations for better water management in Akaroa.

Chapter 4

Methodology

Environmental economics uses a number of methods to estimate market and non-market values. This study will use choice analysis to estimate the value of different RWHS and GWRS to the residents in Akaroa.

4.1 Theoretical Background of Choice Analysis

Random utility theory (RUT) states that the utility of an individual choosing a particular alternative is divided into two parts. One part being observed by the analyst (measurable component), and another part being not observed by the analyst (random component). Under RUT in choice analysis, it is assumed that these two parts of utility are independent and additive.

Overall utility of a specific alternative i is $\mathrm{U_i}$. Following Hensher, Rose, and Greene (2005, p. 75), $\mathrm{U_i}$ can be expressed as:

$$\mathrm{U_i} = \mathrm{V_i} + \varepsilon_\mathrm{i}$$

Where $\mathrm{V_i}$ is measurable utility from the sources observed by the analyst, and ε_i refers to the random (or unobserved) influences as error. The choice set is defined as a choice of $\mathrm{j} = 1, \dots, \mathrm{i}, \dots \mathrm{J}$ alternatives. In which J is the number of alternatives presented to an individual in the choice set.

$\mathrm{V_i}$ can be a linear additive form equation.

$$\mathrm{V_i} = \beta_{0\mathrm{i}} + \beta_{1\mathrm{i}}\mathrm{f}(\mathrm{X_{1i}}) + \beta_{2\mathrm{i}}\mathrm{f}(\mathrm{X_{2i}}) + \beta_{3\mathrm{i}}\mathrm{f}(\mathrm{X_{3i}}) \dots + \beta_{\mathrm{Ki}}\mathrm{f}(\mathrm{X_{Ki}})$$

Where $\beta_{1\mathrm{ki}}$ is the parameter associated with attribute $\mathrm{X_k}$ and alternative i. $\beta_{0\mathrm{i}}$ is a parameter not associated with any of the observed attributes, and is known as the alternative specific constant (ASC). There are K attributes in the equation. $\mathrm{f}(\dots)$ represents a general functional form, this form can be different for each attribute Hensher et al. (2005, p. 76).

When choosing from a set of alternatives, $\mathrm{j} = 1, \dots, \mathrm{J}$, an individual will choose the alternative with the maximum utility. Therefore the probability of an individual choosing alternative i is given by the following equation:

$$\mathrm{Prob_i} = \mathrm{Prob}\left[(\mathrm{V_i} + \varepsilon_\mathrm{i}) \geq \left(\mathrm{V_j} + \varepsilon_\mathrm{j}\right) \forall\, \mathrm{j} \in \mathrm{j} = 1, \dots, \mathrm{J}; \mathrm{i} \neq \mathrm{j}\right]$$

Under the IID (independently and identically distributed) assumption for the random components (ε_i), and imposing the extreme value type 1 (EV1) distribution on the random component allows specification of unobserved utility. The probability of choosing alternative i in the multinomial logit (MNL) model (conditional logit model) is (Hensher et al., 2005, p. 85):

$$\mathrm{Prob_i} = \frac{\mathrm{expV_i}}{\sum_{\mathrm{j}=1}^{\mathrm{J}} \mathrm{expV_j}}; \mathrm{j} = 1, \dots, \mathrm{i}, \dots, \mathrm{J} \;\; \mathrm{i} \neq \mathrm{j}$$

Where, $\mathrm{Prob_i}$ is the probability of an individual choosing the ith alternative out of the choice set of J alternatives. $\mathrm{V_i}$ and $\mathrm{V_j}$ are the utilities from the sets of attributes associated with the ith and Jth alternatives.

4.2 Stated Preference (SP) and Choice Experiment (CE) Method

Both SP and revealed preference (RP) techniques have been widely used for the estimation of market and non-market values. In this study, although RWHS and GWRSs are market goods, estimating people’s WTP for future installation is still an estimation of preferences in a hypothetical market context (Tapsuwan et al., 2014). Since RP techniques are based on people’s actions rather than their intentions, it is necessary to apply a SP technique in this study to measure preferences of people who have not purchased such systems (Bennett & Blamey, 2001, p. 4).

Contingent valuation (CVM) and CE are the two main methods in the family of SP techniques. To elicit people’s preferences, both these techniques involve asking respondents to state their preferences for alternative circumstances (Bennett & Blamey, 2001, p. 3). SP techniques including CVM and CE have been commonly applied to estimate both use and non-use values of non-market goods (Bennett & Adamowicz, 2001). However, CVM does not allow the researcher to value multiple goods or levels of goods. Also, strategic bias is a notable limitation of CVM, among other biases (Bennett & Blamey, 2001, p. 4). In practice, CVM has proven to be expensive and inflexible. Therefore, CVM will not be used in this study.

The CE method was originally designed to predict market share when a new product enters into the market (Bennett & Blamey, 2001, p. 6). Unlike CVM, CE provides alternative levels of various “attributes” of the products or goods for the respondents to choose among. The choice sets are carefully designed before the survey is conducted so that the resulting data will satisfy a range of estimation requirements (Louviere, 2001, p. 13). Tapsuwan et al. (2014) use CE to estimate WTP for decentralised water systems due to its flexibility and ability to value several alternatives concurrently. This study adapts Tapsuwan et al. (2014)'s methods to the Akaroa context.

4.3 Heterogeneity and Models

The assumptions of different models treat people's preference in two ways. One is assuming the preferences are homogeneous across the sample while another assumes there is heterogeneity in people's preferences. Accounting for preference heterogeneity is useful for estimating unbiased models (Boxall & Adamowicz, 2002). Although it is sensible to expect Akaroa people's preferences, in this case, are likely to be heterogeneous, confirmation of that hypothesis and the form of any heterogeneity relies on empirical testing.

Because of uncertainty about the nature of heterogeneity and the error distributions in Akaroa, it was decided not to adopt a particular estimation model ex ante. Instead, a set of standard models were considered in the estimation stage. The models included multinomial logit (MNL) models, error component models (ECM), scaled multinomial logit (SMNL) models, latent class (LC) models and random parameter models (RPM). Model choice was ultimately dictated by data availability and the relative performance of these models against goodness of fit criteria in the data analysis stage. The preferred model based on these criteria will be introduced in the results section.

4.4 Survey Design

4.4.1 Pilot Study

The objectives of the pilot study were

(1) to test attribute levels for tank size and types of greywater systems (filtered and non-filtered) to identify suitable levels for these attributes in the CE design.

(2) to determine the price attribute levels in the CE design.

The pilot study sample was selected by visits to randomly selected homes in Akaroa, in which the homeowner was interviewed. A brief introduction was given to each participant including the aim of this study and background information about decentralised water management systems. Pictures demonstrated the systems to the participants. Pilot study participants were asked a series of questions regarding their WTP for decentralised water management systems. The initial approach asked open-ended questions - "How much would you be prepared to pay for this system which allows you to bypass the water restriction?" However, eight out of the first eleven respondents calculated the cost of water and the pay-off period of the alternative water management systems, so were focussed on cost rather than WTP.

Therefore, a revised approach was used. For each system, the following set of questions was asked.

- "If the certain alternative water supply system could be installed for free, which would allow you to bypass the water restriction, would you have it? (Question 1)"
- If the participant's answer to that question was "Yes." Then the participant would be asked "If you have to pay $100 for the system, would you have it?"
- The number increased by $100 at a time with the follow-up questions if the participant had given a "yes" to the previous question until he/she gave a negative response.
- Often, the participant could understand the aim of these questions (identification of maximum WTP for each decentralised water management system) after the first set of questions. In those cases, the following questions would be asked if the participants answered "yes" to Question 1. "How much would you be prepared to pay at most for this system which allows you the bypass the water restriction?"

The revised approach worked well for an additional 18 respondents. In general, respondents indicated they were willing to pay more for RWHS rather than GWRS. Also, among the three proposed sizes of rainwater tanks (i.e. 5,000L, 10,000L and 25,000L), 5,000L was the most preferred, followed by the 10,000L tank. Only one respondent would pay for a 25,000L tank. There was no significant difference in WTP between filtered and non-filtered greywater systems.

Therefore, only two tank sizes were included in the final study (5,000L and 10,000L) due to the lack of interest in 25,000L tanks. The two greywater systems were retained. The following assumptions were developed from pilot study results.

(1) Inertia costs are -$500. This is a measure of the homeowner's cost of change from the status quo.

(2) WTP for RWHS with a 5,000 litre tank is $1,000.

(3) WTP for RWHS with a 10,000 litre tank is $2,000.

(4) WTP for a non-filtered greywater system is $1,000.

(5) WTP for a filtered greywater system is $2,000.

(6) Interaction of 5,000 litre tank and greywater system is -$200. This is the negative effect on WTP when a 5,000L tank and a GWRS are installed together.

(7) Interaction of 10,000 litre tank and greywater system is -$500. This is the negative effect on WTP when a 10,000L tank and a GWRS are installed together.

The final attributes and levels are shown in Table 4.1.

Table 4.1 Attributes and levels

Attributes	Levels
Rainwater harvesting system tank size	None
	5,000L
	10,000L
Greywater system type	None
	Non-filtered
	Filtered
Price	$0
	$1,500
	$3,000

To construct the CE survey, an optimal experimental design was generated under the assumptions above. Optimal experimental design, also known as statistically efficient design, optimizes the amount of information obtained from a design. The advantage of an optimal design is it will be statistically efficient, but the design will likely have correlations between attributes within the design (Hensher et al., 2005, p. 152). Based on the information on maximum WTP from the pre-test, a D-optimal design for an MNL model minimised D-error (Hensher et al., 2005, p. 153) was conducted using Ngene statistical software. The experimental design had 64 choice sets, which were blocked into eight blocks (versions of survey), with eight choice sets for each block.

4.4.2 Questionnaire

The structure of the questionnaire was inspired by Tapsuwan et al. (2014). There were six sections in the questionnaire (see Appendix B).

Section 1 was the introduction and the purpose of the study.

Section 2 consisted of questions about ownership and occupancy of the house, property characteristics (e.g. property size, roof area, garden size etc.) and water use.

Section 3 introduced the decentralised water management systems. RWHS and GWRS were illustrated through conceptualised pictures. All levels of tank size and greywater system attributes were presented in photos. In this section, survey respondents were given the following guideline for water use:

> *"As a guide, an average individual uses 333L of water every day. If you have a 5,000 litre rainwater tank as your only source of water for a two person household, a full tank would last 7 days (with no rain refill)."*

Section 4 asked questions about current alternative water supply systems at the property.

Section 5 was the CE questions. Three options (Option I, II and III) were provided for each choice set. Option III, the status quo option, was identical in each choice set. The following table is an example of a choice set. Respondents were presented with eight choice sets offering different levels of the three attributes, and were asked to choose their favoured option from each pre-defined set.

Section 6 comprised a set of standard demographic questions. Age, annual household income and occupation etc. were asked in this section.

Table 4.2 Example of a choice set (choice sets were the same in the both hard copy and online surveys)

"If only these three options were available for consideration, which would you prefer?"

	Option I	Option II	Option III
Rainwater system tank size	5,000 litre tank	None	I prefer to choose none of these options and stay with my current water supply
Greywater system	None	Filtered system	
Price	$0	$1,500	
Your choice (tick one box)	☐	☐	☐

4.5 Data Collection

4.5.1 Sampling

The target population for this research was the owners of occupied dwellings in Akaroa. This excluded all tenants and travellers residing in this area, and it also did not include the owners of unoccupied houses. According to the 2013 census, there were 342 occupied dwellings in Akaroa, which had a base population of 624 people (Statistics New Zealand, 2013). The sample was drawn from all owners of identified occupied dwellings. The house owner was the sample unit. The target population in this study were required to have the ability to install the decentralised water system for their house, so initial screening was conducted to test that. Non-home owners and people with inability to authorise adoption of alternative systems were excluded.

4.5.2 Respondent Recruitment and Data Collection

In order to recruit enough respondents to meet the minimum sample size requirement within a month, a tailored respondent recruiting and data collection method was undertaken after evaluation of several common methods with respect to resources available for this study (e.g. budget, time).

The 2016 Habitation Index (Electoral Commission, 2016) purchased from New Zealand Electoral Commission for the study area was used to guide the recruitment. People registered on the Index in Akaroa were visited through door-knocking to deliver the survey invitations.

Personal drop off/mail back with targeted recruiting was preferred in terms of relatively low cost and high chance of getting usable results (Dillman, 2014, pp. 47, 401, 419-421). During the survey distribution, more owner-occupied houses were identified through conversations with participants. These were added to the potential pool of participants. All streets within the Akaroa township area were visited during respondent recruitment. When delivering the survey packages, an oral introduction of this project was given to the participants. The introduction was about 5 minutes long, and it briefly covered the critical information of this survey for respondents. Almost all of the survey packages were delivered to homeowners through door-knocking. In some cases, the homeowners were not at home, in which case a survey package was left in their mailbox.

Survey information was printed on A4 paper, enclosed in an envelope, and was hand delivered to participants with a cover letter and a freepost return envelope. Respondents were entered in a draw for $100 prizes (five winners in total).

According to the 2013 census, 75.3% of NZ households had access to the Internet (Statistics New Zealand, 2013). Therefore, a URL for the online version of the survey was printed on each hardcopy of the questionnaire to provide an alternative response mode. Participants could choose their preferred way of responding. The aim of dual response modes was to make it easier for people to complete, potentially raising the response rate. The contents of the two survey versions were the same.

Chapter 5

Results

Empirical data for this analysis was collected from 14 April to 29 April 2017. Survey packages were handed out to homeowners in 187 houses in Akaroa, where respondents were recruited through door-knocking. Only one homeowner refused the invitation in the distribution stage. Seventy-one surveys were posted back, for a response rate of 38.2%. Excluding three late responses and 14 incomplete surveys, there were 55 respondents entered into the data analysis stage.

5.1 Descriptive Statistics

Descriptive statistics from the survey are displayed in the following table.

Table 5.1 Descriptive statistics of the sample

Demographic Statistics		N	Percent (%)	Akaroa: 2013 census (%)
Age	Under 65	16	29.1	68.7
	65-75	26	47.3	31.3 (65 and over)
	Over 75	13	23.6	
	Total	55	100	
	Median	72		
	Mean	69.6		
Gender	Male	35	63.6	47.6
	Female	20	36.4	52.4
Ethnicity	European	51	92.7	93.8*
	Other ethnicities	4	7.3	13.4*
Occupation	Retired	36	66.7	
	Professional	8	14.8	
	Other occupations	10	18.5	
	Total	54	100.0	
Education	No qualification	4	7.3	18.0
	Level 1-6 qualifications	35	63.6	62.8
	Bachelor's degree or higher	16	29.1	19.2
	Total	55	100.0	
Annual household income	30,000 or less	8	14.6	
	30,001-50,000	17	30.9	
	50,001-70,000	11	20.0	
	70,001 or more	19	34.5	
	Total	55	100.0	
Public water connection	On public water	53	98.1	
	Not on public water	1	1.9	
Water usage	Low	23	41.8	
	Medium	29	52.7	
	High	3	5.5	
Property Characters		**Median**	**Mean**	**Std. Deviation**
Section size (m^2)**		628	725	281
Garden size (m^2)**		298	375	291
Garden percentage (%)**		50	47.6	17.1
Number of bedrooms		3	3.2	0.9
Number of floors		2	1.9	0.8
Number of bathrooms		2	1.8	0.7
Number of adults		2	1.9	0.4
Number of children		0	0.1	0.5

Notes:
*, the values do not add up to 100 as multiple responses were possible.
**, excludes one extremely large property.

Respondents ranged in age from 40 to 88 years. The median age for the sample was 72 years, compared with 54.8 years of age for Akaroa residents in the 2013 census. Respondents of 65 years or older accounted for 70.9% of the sample, compared with only 31.3% for Akaroa in the census. The sample population was therefore relatively old when compared to the Akaroa population at large. Given that the participants in this study were exclusively homeowners, and that recruitment relied on the individuals being home at the time the initial contact was made, it was not surprising that they were relatively older than the general population. Although males and people with no formal education were slightly over-represented in the study sample, the ethnic mix of the respondents was similar to that of the Akaroa population.

With respect to occupation and education, two-thirds of the respondents were retired. For others, the most common occupation category was professional (14.8%). About sixty-three percent of respondents held a qualification on level 1 to 6 as their highest qualification. The proportion was about the same as in the census. Bachelor's degree or higher level of qualification was held by 29.1% of the sample, compared with 19.2% of people in the census. Low annual household income ($50,000 or less) accounted for 45.5% of the sample, while more than a half (54.5%) households in the sample earned $50,001 or more annually.

With one exception, all respondents were connected to the public water supply, and the majority of the respondents considered themselves low-to-medium users of water. Except one, all respondents reported their properties had a garden. The percentage of the section covered in garden ranged from 20% to 95%. Half of the sample reported their gardens accounted for 50% or more of their sections.

Regarding home composition and occupancy, two bathrooms per house was the most common (43.6%) in the sample. The mean number of adults living in each property was 1.9, compared with the census, where the average household size in Akaroa was 2.0 people. Most respondents (89.1%) had no children under 18 living in the house.

With respect to existing decentralised water supply, only 7 respondents (12.7%) reported having a rainwater tank on their sections. Even fewer (5 respondents, or 9.1%) reported reusing greywater, and four of these individuals were using manual bucketing. Only one respondent reported having a non-filtered greywater system, and another respondent has a filtered system for greywater.

5.2 Model Selection

A range of statistical models, including the simple multinomial logit (MNL) model, the error components (EC) logit model, the scaled multinomial logit (SMNL) model, the latent class (LC) model and the random parameter logit (RPL) model were examined to identify the most suitable model for this empirical data. The statistical analysis was conducted using Nlogit version 5.0 software. The criteria used to compare model fit were the standard information criteria (IC). Akaike's Information Criterion (AIC), the Bayesian Information Criterion (BIC), Bozdogan's consistent AIC (CAIC), and the adjusted BIC (ABIC) were all compared for each model along with adjusted Pseudo (McFadden’s) R^2 relative to the constants only model.

The results of the empirical tests for model selection are listed in Table 5.2. To determine whether the models have captured all utility-relevant aspects of decentralised water supply choice, the significance of alternative specific constants (ASC) was tested for each model. ASCs were included in non-SQ utility functions. Except for the SMNL model, the addition of ASCs improves model fit. In the initial scope of these models, a two-class latent class (LC) model with an alternative-specific constant has the lowest IC values and the largest Adjusted R^2 value. Therefore, a LC model was selected for further analysis (see Table 5.2, best scores are shaded).

Table 5.2 Comparison of models

Goodness of fit Values	**ECM**		**LC (2 classes)**		**MNL**		**RPM**		**SMNL**	
	No ASC	With ASC	No ASC	With ASC	No ASC	With ASC	No ASC	With ASC	No ASC	With ASC
AIC3	1.818	1.777	1.147	1.081	1.801	1.761	1.244	1.233	1.286	1.320
CAIC	1.881	1.849	1.258	1.228	1.801	1.808	1.316	1.313	1.382	1.432
BIC	1.867	1.832	1.232	1.193	1.831	1.797	1.299	1.295	1.360	1.406
ABIC	1.819	1.779	1.149	1.083	1.802	1.762	1.246	1.236	1.289	1.323
Adjusted R^2	-0.011	0.015	0.388	0.439	-0.009	0.017	0.318	0.327	0.306	0.292

5.3 Refined Latent Class Model

Unlike the conventional conditional logit model (i.e. MNL model), the LC model does not assume homogeneous preferences across the sample. It allows the analyst to identify a number of classes of respondents whose preferences may vary between, but not within, each class (Tapsuwan et al., 2014). The LC model estimates the choice parameters and class membership simultaneously (Boxall & Adamowicz, 2002). This approach is able to explain the source of heterogeneity by incorporating and adding structure to the distribution of unobserved heterogeneity (Putten, Jennings, Louviere, & Burgess, 2011). Understanding the source of heterogeneity also provides useful information to answer the questions for this project's objectives.

The LC model imposes the assumption that utility parameters are constant across all respondents within each class, while the parameters may be different among classes. Denote the individual who is making the choice as n, and denote class as c. The probability, conditioned on class membership, that an individual n chooses alternative i from a choice set containing J alternatives takes the following form (adapted from (Boxall & Adamowicz, 2002; Tapsuwan et al., 2014)):

$$\mathrm{Prob}_{\mathrm{n|c}}(\mathrm{i}) = \frac{\exp(\mu_c \beta_c X_{ni})}{\sum_{j=1}^{J} \exp(\mu_c \beta_c X_{nj})}; j = 1, \dots, i, \dots, J \quad i \neq j$$

Where β_c is a vector of class-specific utility function coefficients, and μ_c is the scale parameter. X_{ni} is the vector of the attributes of alternative i for individual n.

Denote Z_n as the vector of both P_n and S_n, which consists of latent psychometric constructs (P_n) and observed sociodemographic characteristics (S_n) of individual n (Boxall & Adamowicz, 2002). Then denote the probability of membership in class c as π_{nc}, which is modelled as a function of Z_n. Using a multinomial logit model, the class membership probability is:

$$\pi_{nc} = \frac{\exp(\alpha \lambda_c Z_n)}{\sum_{c=1}^{C} \exp(\alpha \lambda_c Z_n)}; s = 1, \dots, S$$

Where α is a scale factor and λ_c is a vector of parameters. Therefore, the probability individual n chooses alternative i across J choice sets for a given number of classes C is equal to $\sum_{c=1}^{C} \pi_{nc} \prod_{j=1}^{J} \mathrm{Prob}_{\mathrm{n|c}}(\mathrm{i})$. Alternatively:

$$\mathrm{Prob}_{ni} = \sum_{c=1}^{C} \left[\frac{\exp(\alpha \lambda_c Z_n)}{\sum_{c=1}^{C} \exp(\alpha \lambda_c Z_n)} \right] \left[\frac{\exp(\mu_c \beta_c X_{ni})}{\sum_{j=1}^{J} \exp(\mu_c \beta_c X_{nj})} \right]; \ j = 1, \dots, i, \dots, J \quad i \neq j$$

Empirically, the scale factors α and μ_c are set equal to one for identification purposes (Boxall & Adamowicz, 2002).

Two equations were derived from the LC model for the relative utility of choosing a particular option. V_{nonsq} represents the utility of choosing a non-SQ alternative (Option I or Option II), V_{sq} is the utility of choosing the status quo.

$$V_{nonsq} = \beta_s ST + \beta_b BT + \beta_f FILT + \beta_{nf} NONFILT + \alpha_{pr} PRICE$$

In the model structure associated with the non-SQ alternatives there are five independent variables. ST and BT are dummy variables for the 5,000L and 10,000L rainwater tanks, respectively. For the GWRS, the filtered system dummy variable is FILT while the non-filtered system dummy variable is NONFILT. The variable PRICE represents the cost attribute associated with each option. Parameters for the independent variables are defined as β_s, β_b, β_f, β_{nf} and α_{pr}, respectively.

$$V_{sq} = SQASC + \beta_A AGE + \beta_W W1 + \beta_{hinc} HIGHIN$$

V_{sq} is specified with an alternative specific constant SQASC and three independent variables; AGE, W1, and HIGHIN. Descriptive statistics for these variables can be found in Table 5.1. For modelling purposes, the independent variables have been re-specified slightly. AGE is the age of the respondent in years. W1 is a dummy variable for low water use, equal to 1 if water use is reported as low, and zero otherwise. HIGHIN is a dummy variable for annual household income, equal to 1 if income was reported to be $50,001 or above, and zero otherwise. β_A, β_W and β_{hinc} are the parameters associated with these independent variables. SQASC estimates the constant specific to the status quo.

Using the coefficients estimated, one can calculate the WTP value for each attribute. Denoting the WTP for a particular type of decentralised water management system as WTP_D, The formula is.

$$WTP_D = -\beta_d / \alpha_{pr}$$

Where β_d represents the parameter associated with a particular water management system (e.g. a RWHS with a 5,000L tank).

This two class LC model has the lowest IC scores and an adjusted Pseudo R^2 value of 0.615 (see Table 5.3). Hensher et al. (2005, pp. 338-339) suggest that for a discrete choice model a Pseudo R^2 above 0.3, means the model fits decently.

In this case, the sample was relatively small (N=440, 97 observations have been skipped due to missing values). Models with 1 to 4 preference classes were examined. Only models with one and two classes could be estimated, as the models with 3 and 4 classes failed to converge. Two class models were uniformly superior to one class models. Every independent variable had been tested for significance as a class allocation variable, but none were significant. Among all the independent variables, AGE, W1, and HIGHIN were significant determinants of utility in the two class LC model.

5.4 Model Estimation Results

Table 5.3 presents the estimates of the coefficients, along with their standard errors for the two class latent class model. Class 1 shows medium to high significance for all estimated parameters. The explanatory variables in class 2 are all significant except NONFIL and AGE, and SQASC is significant only at the 10% level. The probability of class membership (i.e. π_{nc}, shown as PrbCls in Table 5.3) for class 1 is 63.1% (n=35) and for class 2 is 36.9% (n=20). Both are significant at 1% level.

The main difference between the two classes is the negative sign of the coefficient associated with the alternative water supply systems in class 1, while in class 2 they are all positive, although NONFIL is not significant for class 2. This implies that in general, the respondents in class 1 dislike the idea of having any of the alternative water supply systems evaluated in this study. They would have less utility from adding RWHS and GWRS on their property rather than making no change. The respondents in class 2, however, are in favour of most types of alternative water supply systems. Positive and highly significant coefficients associated with ST, BT and FILT in class 2 indicate that class 2 members gain utility from the RWHS (with either a 5,000L tank or a 10,000L tank) and the filtered greywater system. The lack of significance on the coefficient of the NONFIL variable in class 2 implies that a nonfiltered greywater system does not have a significant effect on utility for respondents in class 2. PRICE coefficients are negative and highly significant in both categories.

The coefficient associated with age is highly significant and has a positive sign in class 1, which means within class 1, age has a positive marginal effect on the relative utility from choosing the status quo. While in class 2, this variable does not have a significant effect on utility.

In both classes, W1 coefficients are positive and highly significant. Within each class, respondents who considered themselves to be low water users are significantly different from those who reported as medium and high water users. Low water users are more likely to choose the status quo.

The coefficient of HIGHIN is highly significant and positive in class 1. This means high-income members in class 1 are more likely to retain the status quo. In contrast, a significant negative coefficient of HIGHIN in class 2 implies the high-income group in class 2 are more likely to change from the status quo than others in class 2.

Notably, the values of SQASC in both classes are negative and highly significant. This, however, does not mean, all else being equal, making no change on current water supply has less utility than choosing the alternatives because the constant is confounded with coefficients for the personal attributes.

On the other hand, in class 2, age does not have a significant effect on $\mathrm{U_{sq}}$. The coefficient of HIGHIN has a negative sign (-2.35), which indicates high-income members in class 2 are more likely to change than others in this class. Only the coefficient of W1 was significant and positive (6.96), which means that only the respondents in this class who considered themselves to be low water users are more likely to stay on status quo.

Table 5.3 Results from 2-class latent class model

	Class 1		Class 2	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
ST	-2.280***	0.877	2.441***	0.440
BT	-3.933***	1.323	2.103***	0.457
FILT	-2.090**	0.982	1.698***	0.465
NONFIL	-2.125**	1.004	0.322	0.362
SQASC	-25.366***	5.244	-12.360*	7.311
AGE	0.321***	0.066	0.126	0.092
W1	3.934***	1.081	6.961***	1.431
HIGHIN	4.015***	1.183	-2.354***	0.894
PRICE	-0.00125***	0.00031	-0.00089***	0.0002
PrbCls	0.631***	0.017	0.369***	0.068
Goodness of fit scores	**AIC3**	**CAIC**	**BIC**	**ABIC**
	0.964	1.150	1.105	0.960
Log likelihood function scores	**Fitted model**		**Restricted model (no coefficients)**	
	-182.132		-483.389	
Adjusted Pseudo R^2	0.615			

Note:
***, **, * stand for significance at 1%, 5%, 10% level.
The estimation is based on N=440, K=19.
Log likelihood function for constants only model is -387.657

5.5 Willingness to Pay

The WTP and standard errors in Table 5.4 are modelled with the Wald function in Nlogit version 5.0 software with 10,000 replications. As discussed above, class 1 members dislike the additional water supply systems. Table 5.4 shows estimates of WTP to install a RWHS or a GWRS. Class 1 has negative WTP. In other words, full price subsidies plus compensations of $1,824 and $3,145 are needed for class 1 members to adopt a RWHS with a 5,000L tank or a 10,000L tank, respectively. For GWRS, full subsidies plus compensations of $1,672 (on filtered systems) and $1,699 (on non-filtered systems) are necessary for class 1. There was no significant difference in WTP between the alternative rainwater tank sizes or between the alternative GWRS.

Class 2 respondents are prepared to pay for RWHS and filtered greywater systems. The highest WTP is $2,749 for a RWHS with the 5,000L tank. WTP for a system with the 10,000L tank is slightly lower at $2,369, but the difference is not significant. WTP for a filtered greywater system is $1,912. In contrast, WTP for a non-filtered greywater system is not significantly different from zero, and it is significantly lower than a filtered greywater system with a $1,550 difference.

Table 5.4 Household WTP for decentralised water management systems (in Q1 2017 NZD)

	Class 1		Class 2	
	WTP	**Standard error**	**WTP**	**Standard error**
[A] 5,000L Tank	-1824**	760	2749***	550
[B] 10,000L Tank	-3145**	1273	2369***	451
[C] Filtered GWRS	-1672**	853	1912***	440
[D] Non-filtered GWRS	-1699*	881	363	395
[A] – [B]	-1322	995	-380	400
[C] – [B]	-28	513	-1550***	370

Note: ***, **, * stand for significance at 1%, 5%, 10% levels.

Chapter 6

Conclusion and Discussion

6.1 Perceptions of Rainwater Harvesting Systems and Greywater Reuse Systems

The results of the LC analysis suggests heterogeneity of preferences for decentralised water management systems within the homeowners in Akaroa from which the sample is drawn. This means that the decentralised water management systems are valued differently between preference classes. Although determinants of class membership cannot be identified in this study, personal factors such as age, water use level and household income are significant components of utility in one or both of the classes. Unlike the findings from the study by Tapsuwan et al. (2014), the majority of the sample dislike the idea of installing decentralised water management systems.

The members of class 1, who are nearly two-thirds of the sample, have negative WTP across all decentralised water management systems studied in this research. In this class, elderly people are more likely than younger people to choose the status quo. This is consistent with evidence collected during the pilot study and survey distribution. Some participants said they were too old to have those systems, even though they thought installation of the systems were a good idea. Low water users are less likely than others to adopt these additional water management systems compared. This makes sense because low water users will be less-affected by restrictions.

Class 2, more than one-third of the sample, have a positive preference towards these systems. Highly significant positive WTPs for RWHS and filtered GWRS suggest that the respondents in this class value the systems positively. In this class, age do not have a significant effect on utility. People who consider themselves to be low water users are not likely to install these ‘extra' water management systems compared to people who consider themselves to be medium or high water users. Respondents with high annual household income will be more likely to pay for these systems.

It is worth noting that in both classes, the respondents who identify themselves to be low water users are less likely to pay for decentralised water management systems. These respondents may think they have an adequate amount of water, so the systems will not be of value to them. It is also possible that low water consuming homeowners believe they are not the ones who cause water shortages, therefore they do not have the responsibility to fix it and will retain the status quo.

6.2 Study Limitations

One of limitations of this study is the potential for bias from sample selection. The relatively small sample size (complete responses from 55 respondents) represents a small, non-representative section of the population. The survey obtains responses from 29% of the 187 houses visited. The selection of the 187 houses is guided by the habitation index for a better chance of reaching resident owners. However, the Habitation index can be biased because registration of the index does not necessarily match actual occupancy. During the survey distribution, most owners of holiday homes and rented houses could not be reached. The personal delivery approach and short period for delivery also constrain the number of surveys distributed. Biases could occur during the personal delivery. For example, potential participants may have rejected the invitation if they do not like the research person. Possible methods to enlarge the sample size and cover more potential participants in the population include conducting a second or third visit to homes where the first visit was unsuccessful. A longer survey distribution timeframe could provide the opportunity for more holiday homeowners to receive the survey. If the time for delivering the survey was doubled, the survey could have covered the whole population (342 occupied houses). With a larger sample, the biases will be mitigated further. Other models may turn out to be more suitable for the estimation, and the significance of estimated coefficients may increase.

Another point for improvement is the identification of holiday home owners. Akaroa has a large number of holiday homes. The owners of holiday homes and the owners who are permanent residents may hold quite different preferences towards the installation of decentralised water management systems. This project assumes the majority of the homeowners visited would be permanent residents due to the findings from the pilot study. However, the main survey distribution takes place in a short period covering the Easter holidays. A respondent states that in her complete questionnaire “This is only a holiday house, if we lived here, our answers would probably be different." Another notes, "Bach, so not used often." Hence, there are some holiday home owners in the sample. A question differentiating holiday home owners and permanent residents in the questionnaire would have permitted testing of residence effects. Leaving the survey packages in the mailboxes of houses with absent homeowners and allowing longer response time can potentially increase the number of responses from holiday home owners.

Inability to identify the determinants of class membership may relate to the points mentioned above. Comments from the respondents suggest there could be a difference in preferences towards decentralised water management systems between holiday home owners and other home owners. Other variables may also have been significant class membership determinants with a larger sample size.

6.3 Comparison with Actual Market

Since class 1 has negative WTP across all types of decentralised water management systems, its members require compensation to adopt free systems of any type. The amount of incentives needed would be $5,824, $8,200, $8,672 and $4,200 for RWHS with 5,000L tank, RWHS with 10,000L tank, filtered GWRS and nonfiltered GWRS, respectively.

In class 2, comparing the positive and significant WTP to the market cost of the systems, mean WTP for both types of RWHS and filtered GWRS were below the market cost. Subsidies, therefore, are required for respondents in class 2 to adopt the systems. RWHS with a 5,000L tank and a 10,000L tank require relatively low subsidies, about $1,250 and $2,700, respectively. This means if the external benefit from installing a RWHS with a 10,000l tank exceeds the external benefit from installing a RWHS with a 5,000l tank by $1,450, the RWHS with the larger tank would be more worthwhile to subsidise in terms of attaining maximum social benefit. A filtered GWRS requires more than $5,100 subsidy for homeowners to install. A non-filtered GWRS needs full price subsidy ($2,500) to adopt as WTP is not significantly different from zero.

6.4 Public Policy Implications

The results in this study show that the RWHS with a smaller tank is the most preferred system for the respondents in class 2. Encouraging the adoption of small tanks is therefore a promising way to initiate a decentralised water management system. The relatively low cost for subsidising small tanks is the main reason for promoting this system. However, there may very well be ancillary benefits associated with the larger tank, such as additional water security in severe weather events that have not been considered here. If this is the case, and if these ancillary benefits have significant social value, then moving directly to the larger tank may be preferred.

Comparing to other systems RWHS with 5,000L tank requires the lowest amount of total subsidies for the respondents in class 2. A rebate of $1,250 for each installation would achieve 36.9% of adoption for this system. If the marginal external benefit of installing RWHS with 10,000l tank is greater than $1,450, then subsidising the RWHS with 5,000L tank is better off. This option also complies with the current bylaw and regulations. The current regulation requires new constructions in Akaroa to install a 5,000L water tank for rainwater collection (Christchurch City Council, 2014). It, however, does not encourage the installation for existing houses. If the financial incentive for the system was available for existing homeowners, the adoption rate could be considerable.

Another reason for promoting a RWHS with the 5,000L tanks is the potential that this system has for complementing the Council's proposed future waste water system. The Christchurch City Council has surveyed new waste water treatment schemes for Akaroa. One of the treatment plant options requires a 1,000 m3 water storage pond for severe storm events (Christchurch City Council, 2017). During a severe storm event, storm water could enter into the waste water network and therefore increase the amount of waste water flow up to more than three times the treatment plant capacity (Christchurch City Council, 2017). Decentralised rainwater harvesting can reduce the amount of roof storm water, which would alleviate the burden on the public storm water system, mitigating the risk of water storage pond overflow and increasing the resilience of the public storm water management system in Akaroa. For example, if 36.9% of the population adopt the 5,000L tank system, an additional capacity of 630 m3 of water storage would be achieved at a cost of $0.25 per litre in subsidies. However the additional storm water resilience is dynamic as the water tanks would not necessarily be empty at the initiation of an extreme storm event. Whether this represents a good investment in public water storage depends on the cost of alternative storage options.

Given the negative WTP in class 1 and insignificant WTP in class 2, the preference of non-filtered GWRS for the respondents is completely different from the results that Tapsuwan et al. (2014) found. Despite the negative impression of non-filtered GWRS from the respondents, it requires a subsidy of $2,500 per installation to achieve 36.9% adoption and an extra $1,700 per installation for full adoption of the system. The low actual market price for the system is the main reason for having the lowest amount of subsidy for adoption comparing to other systems. It requires at least $1.22 million for subsidies to achieve the full adoption of non-filtered GWRS in Akaroa. The potential and total benefit of this option needs to be considered with other alternatives by policy makers.

Although this project has some potential for improvement, it helps fill the gap in the literature evaluating decentralised water management systems in New Zealand. The homeowners in Akaroa are reluctant to change the status quo in general. The difference in between is relatively large for most of the respondents. The most promising result is one-third of the sample are willing to partially pay for some of the systems. This study has measured the difference between private benefits and private costs through estimating WTP for decentralised water management systems. It therefore allows identification of the feasibility and order of costs of using financial incentives to encourage homeowner adoption of these options. This research also sheds some lights to the determinants affecting system adoption. The information provides a useful baseline for further studies on this issue.

Appendix A

Water restrictions guide from Christchurch City Council

Restriction Level	Water Conservation Method
Level 1 - Alternative day watering	i. Use of hoses, sprinklers and garden irrigation systems is permitted on alternative days ii. Even numbered properties on even days iii. Odd numbered properties on odd days.
Level 2 - Hand held hosing only	• Hand-held hoses may be used at any time • Unattended hoses, sprinklers, and garden irrigation systems are not permitted at any time.
Level 3 - Alternate day hand-held hosing only	• Hand-held hoses may be used on alternative days • Even numbered properties - hand-held watering only on Tuesdays, Thursdays and Saturdays • Odd numbered properties - hand-held watering only on Wednesdays, Fridays and Sundays • Unattended hoses, sprinklers, and garden irrigation systems are not permitted at any time.
Level 4 - Total hosing ban	• All use of water outside the house must cease • Hand held hoses, unattended hoses, sprinklers, and garden irrigation systems are not permitted at any time.

Appendix B

Survey questionnaire

Section 1. Introduction

Welcome to the survey on alternative water supply devices in Akaroa.

Water use is sometimes restricted in Akaroa by the City Council in the summer. You are invited to participate in this survey about how people in Akaroa feel about using different sources of water for household use. I would like to know your views on different options to help me to understand the situation from a community perspective to help me complete my research thesis.

The survey is anonymous - you will not be identified as a respondent. You may withdraw your participation at any time before 15 May 2017, including withdrawal of any information you have provided. Any email, phone call, text or letter asking to withdraw by 15 May 2017 will be accepted.

In order to have the opportunity of withdrawal from the survey, you will be asked to provide your property address so that I can identify the information you provide. If you do not withdraw by 15 May 2017, it will be understood that you have consented to participate in the project and consent to publication of the results.

The survey can also be completed online at:

http://tiny.cc/akaroawater

Or scan this QR code with a smartphone:

(Internet access required)

Section 2. Water use, property character and house occupancy

1. What is your property's address?

____

2. Is your home currently connected to the public water supply?

☐ Yes ☐ No ☐ Don't know/Not sure

3. Please indicate the number of bedrooms, bathrooms and levels your house has:

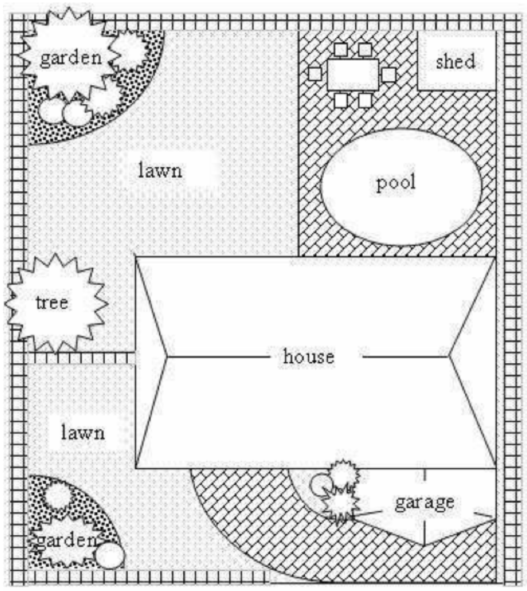
_________ Bedroom(s)

_________ Bathroom(s) (including en-suites and additional toilets)

_________ Storey(s)/floor(s)/level(s)

For the next question, we would like to know how big your garden is, relative to the size of your section. Have a look at the example below to help you answer this question.

For example if this is your home, you can say that your garden and lawn size is approximately **40%** of your entire section size.



4. My garden and lawn size is approximately _______________ % of my section size.

5. Do you consider your household to be a (please tick the most appropriate response)

☐ Low water user

☐ Medium water user

☐ High water user

Section 3. Alternative water supply systems

Two products are of interest in this survey:

Rainwater Tanks and Greywater Systems.

Rainwater Tanks

A rainwater tank (5,000L) in use

(A photo of 5,000L rainwater tank inserts here)

A common domestic rainwater harvesting system (a water pump is optional depending on the location of the water tank)

(A demonstration of rainwater harvesting system picture inserts here)

The dimensions of some common water tank sizes
(The person in following photos is 170cm in height)

5,000 Litre tank

10,000 Litre tank

As a guide, an average individual uses 333L of water every day. If you have a 5,000 litre rainwater tank as your only source of water for a 2 person household, a full tank would last 7 days (with no rain refill).

Greywater systems

Greywater is wastewater that has been generated from laundry, dish washing and showering (but NOT from the toilet) . This water often has a cloudy appearance and can be used for some external applications (e.g. garden/lawn watering) without treatment.

Two available greywater systems are:

1. Greywater diversion system (**non-filtration**) for reuse on gardens/lawns.

This system redirects untreated water from your shower, laundry and kitchen sink to gardens and lawns using below-surface irrigation system (e.g., via drip line buried in the soil, under mulch; or in mulch-filled trenches).

2. Greywater **filtration** system for reuse on gardens/lawns, car/boat washing, toilet flushing.

This system filters the water from your shower, laundry and kitchen, then stores the water in a tank. A pump is optional depending on the location of the storage tank.

A common domestic greywater reuse system

(A picture of domestic greywater reuse system inserts here)

Greywater filtration and pumping unit

(A photo of filtration unit inserts here)

Section 4. Alternative water supply systems at your house

1. Do you use a rainwater tank for private water supply?

☐ Yes

Please indicate the size of your rainwater tank ___________ Litres

☐ No

☐ Don't know/Not sure

2. Do you reuse greywater from within your house in any way?

☐ Yes (please go to **question 3**)

☐ No (please go to **Section 5** – over the page)

☐ Don't know/Not sure (please go to **Section 5** – over the page)

3. How do you reuse greywater in your home? (Tick all that apply to you)

☐ I use buckets to collect and reuse greywater

☐ I connect a hose to a washing machine outlet to reuse greywater

☐ I have a greywater diversion device (non-filtration)

☐ I have a treated greywater device (with filtrattion)

☐ Other (please describe): _______________

Section 5. Preference for alternative water supply systems

Akaroa has experienced water shortages, which have resulted in water restrictions. Increasing household water supplies from rainwater tanks and greywater systems, has the potential to provide additional water throughout the year. The additional water could also help to reduce the severity of water restrictions and provide backup water in case of emergency (e.g. after an earthquake).

The next set of questions asks you to make choices between three possible options. You will be asked to complete 8 different choice tasks. The options are different in each task. For each task please carefully consider the three options proposed (Options I, II and III). If only those three options were available for consideration, which would you prefer?

There are no correct/incorrect answers, we are simply trying to understand how you view the various options.

Choice Task 1, from Block 1

If only these three options were available for consideration, which would you prefer?

<table>
<tr><th></th><th>Option I</th><th>Option II</th><th>Option III</th></tr>
<tr><td>Rainwater system tank size</td><td>5,000 litre tank</td><td>None</td><td rowspan="3">I prefer to choose none of these options
and stay with my current
water supply</td></tr>
<tr><td>Greywater system</td><td>None</td><td>Filtered system</td></tr>
<tr><td>Price</td><td>$0</td><td>$1,500</td></tr>
<tr><td>Your choice (tick one box)</td><td>☐</td><td>☐</td><td>☐</td></tr>
</table>

Note: The above task is an example of a choice task used in the questionaiire. Section 5 of each questionairre included eight distinct choice tasks, with different levels of the three attributes. There are 8 versions the questionnaire, corresponding to the 8 blocks of the experimental design. These are presented in detail in Appendix C

Section 6. Standard demographic questions

1. What is your year of birth? ___________________

2. Are you? ☐ Male ☐ Female

3. Which ethnic group do you belong to? (Mark all spaces which apply to you)

☐ European

☐ Māori

☐ Pacific Peoples

☐ Asian

☐ Middle Eastern

☐ Latin American

☐ African

☐ Other ethnicity

4. What is your household's gross annual income before tax?

☐ $20,000 or less

☐ $20,001 - $30,000

☐ $30,001 - $50,000

☐ $50,001 - $70,000

☐ $70,001 - $100,000

☐ $100,001 or more

5. How many adults (18 years and over) live in your household?

____

How many children (under 18 years) live in your household?

____

6. What is your usual occupation?

☐ Manager

☐ Professional

☐ Technician or trade worker

☐ Community or personal service worker

☐ Clerical or administrative worker

☐ Sale worker

☐ Machinery operator or driver

☐ Labourer

☐ Not in the workforce

7. What is the highest level of education you have achieved?

☐ No qualification

☐ High school qualification

☐ Technical or vocational Certificate

☐ Bachelor’s Degree

☐ Postgraduate Degree

☐ Other qualifications, Please specify:

Thank you very much for your cooperation and contribution to this research. If you have any questions or comments please feel free to contact me.

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Please return your completed survey before 15 May 2017 by placing it in the freepost envelope provided as soon as possible.

The survey can also be completed online at:

http://tiny.cc/akaroawater

Or scan this QR code with a smartphone:

(Internet access required)

Appendix C

Experimental Design

Block 1				
Choice task	**Attributes**	**Option1**	**Option2**	**Base case**
1	Tank	10,000 litre tank	5,000 litre tank	None
	Filter	Filtered system	Filtered system	None
	Price	$0	$0	$0
2	Tank	None	10,000 litre tank	None
	Filter	Filtered system	None	None
	Price	$3,000	$3,000	$0
3	Tank	10,000 litre tank	None	None
	Filter	Filtered system	Non-filtered system	None
	Price	$3,000	$0	$0
4	Tank	5,000 litre tank	5,000 litre tank	None
	Filter	None	Filtered system	None
	Price	$1,500	$3,000	$0
5	Tank	5,000 litre tank	10,000 litre tank	None
	Filter	Filtered system	Non-filtered system	None
	Price	$0	$0	$0
6	Tank	None	5,000 litre tank	None
	Filter	Non-filtered system	Filtered system	None
	Price	$1,500	$3,000	$0
7	Tank	5,000 litre tank	5,000 litre tank	None
	Filter	Non-filtered system	None	None
	Price	$1,500	$0	$0
8	Tank	5,000 litre tank	None	None
	Filter	None	Filtered system	None
	Price	$3,000	$3,000	$0

Block 2				
Choice task	**Attributes**	**Option1**	**Option2**	**Base case**
1	Tank	10,000 litre tank	None	None
	Filter	Filtered system	Filtered system	None
	Price	$1,500	$0	$0
2	Tank	None	5,000 litre tank	None
	Filter	Non-filtered system	None	None
	Price	$1,500	$3,000	$0
3	Tank	10,000 litre tank	None	None
	Filter	Non-filtered system	Filtered system	None
	Price	$3,000	$3,000	$0
4	Tank	10,000 litre tank	10,000 litre tank	None
	Filter	None	Filtered system	None
	Price	$1,500	$3,000	$0

5	Tank	None	10,000 litre tank	None
	Filter	Non-filtered system	None	None
	Price	$3,000	$3,000	$0
6	Tank	10,000 litre tank	None	None
	Filter	None	Non-filtered system	None
	Price	$1,500	$3,000	$0
7	Tank	10,000 litre tank	5,000 litre tank	None
	Filter	Non-filtered system	Filtered system	None
	Price	$0	$0	$0
8	Tank	5,000 litre tank	None	None
	Filter	Filtered system	Filtered system	None
	Price	$0	$0	$0

Block 3

Choice task	Attributes	Option1	Option2	Base case
1	Tank	None	10,000 litre tank	None
	Filter	Filtered system	None	None
	Price	$0	$0	$0
2	Tank	5,000 litre tank	10,000 litre tank	None
	Filter	None	None	None
	Price	$0	$1,500	$0
3	Tank	None	5,000 litre tank	None
	Filter	Filtered system	Non-filtered system	None
	Price	$1,500	$3,000	$0
4	Tank	10,000 litre tank	10,000 litre tank	None
	Filter	None	Non-filtered system	None
	Price	$3,000	$3,000	$0
5	Tank	None	None	None
	Filter	Non-filtered system	Filtered system	None
	Price	$0	$1,500	$0
6	Tank	10,000 litre tank	5,000 litre tank	None
	Filter	Filtered system	Non-filtered system	None
	Price	$3,000	$0	$0
7	Tank	5,000 litre tank	10,000 litre tank	None
	Filter	Filtered system	Filtered system	None
	Price	$0	$0	$0
8	Tank	None	10,000 litre tank	None
	Filter	Non-filtered system	Non-filtered system	None
	Price	$0	$1,500	$0

Block 4

Choice task	Attributes	Option1	Option2	Base case
1	Tank	5,000 litre tank	None	None
	Filter	Filtered system	Non-filtered system	None
	Price	$3,000	$1,500	$0
2	Tank	None	None	None

	Filter Price	Filtered system $1,500	Non-filtered system $3,000	None $0
3	Tank Filter Price	5,000 litre tank Non-filtered system $0	10,000 litre tank None $0	None None $0
4	Tank Filter Price	5,000 litre tank Filtered system $3,000	5,000 litre tank None $1,500	None None $0
5	Tank Filter Price	5,000 litre tank Non-filtered system $3,000	5,000 litre tank None $3,000	None None $0
6	Tank Filter Price	5,000 litre tank None $1,500	None Non-filtered system $1,500	None None $0
7	Tank Filter Price	10,000 litre tank None $0	10,000 litre tank Filtered system $1,500	None None $0
8	Tank Filter Price	10,000 litre tank Non-filtered system $1,500	None Filtered system $1,500	None None $0

Block 5				
Choice task	**Attributes**	**Option1**	**Option2**	**Base case**
1	Tank Filter Price	5,000 litre tank None $0	None Filtered system $1,500	None None $0
2	Tank Filter Price	None Filtered system $1,500	5,000 litre tank Non-filtered system $3,000	None None $0
3	Tank Filter Price	5,000 litre tank None $3,000	None Non-filtered system $1,500	None None $0
4	Tank Filter Price	10,000 litre tank None $1,500	None Non-filtered system $0	None None $0
5	Tank Filter Price	None Filtered system $1,500	10,000 litre tank None $1,500	None None $0
6	Tank Filter Price	None Non-filtered system $3,000	5,000 litre tank None $1,500	None None $0
7	Tank Filter Price	None Filtered system $3,000	10,000 litre tank Non-filtered system $3,000	None None $0
8	Tank Filter Price	10,000 litre tank None $1,500	5,000 litre tank None $0	None None $0

Block 6				
Choice task	**Attributes**	**Option1**	**Option2**	**Base case**
1	Tank	10,000 litre tank	10,000 litre tank	None
	Filter	Non-filtered system	Filtered system	None
	Price	$0	$0	$0
2	Tank	5,000 litre tank	10,000 litre tank	None
	Filter	Filtered system	None	None
	Price	$1,500	$0	$0
3	Tank	5,000 litre tank	5,000 litre tank	None
	Filter	Non-filtered system	Filtered system	None
	Price	$0	$1,500	$0
4	Tank	10,000 litre tank	10,000 litre tank	None
	Filter	None	Non-filtered system	None
	Price	$0	$1,500	$0
5	Tank	10,000 litre tank	5,000 litre tank	None
	Filter	Filtered system	Filtered system	None
	Price	$1,500	$0	$0
6	Tank	10,000 litre tank	10,000 litre tank	None
	Filter	Filtered system	Non-filtered system	None
	Price	$0	$0	$0
7	Tank	None	5,000 litre tank	None
	Filter	Filtered system	None	None
	Price	$3,000	$1,500	$0
8	Tank	5,000 litre tank	10,000 litre tank	None
	Filter	Non-filtered system	Filtered system	None
	Price	$3,000	$3,000	$0

Block 7				
Choice task	**Attributes**	**Option1**	**Option2**	**Base case**
1	Tank	10,000 litre tank	None	None
	Filter	None	Filtered system	None
	Price	$3,000	$3,000	$0
2	Tank	None	5,000 litre tank	None
	Filter	Non-filtered system	Non-filtered system	None
	Price	$1,500	$1,500	$0
3	Tank	10,000 litre tank	5,000 litre tank	None
	Filter	None	None	None
	Price	$1,500	$3,000	$0
4	Tank	None	5,000 litre tank	None
	Filter	Non-filtered system	Non-filtered system	None
	Price	$3,000	$3,000	$0
5	Tank	None	10,000 litre tank	None
	Filter	Non-filtered system	Filtered system	None
	Price	$0	$3,000	$0

6	Tank Filter Price	None Filtered system $1,500	None Non-filtered system $0	None None $0
7	Tank Filter Price	None Filtered system $0	10,000 litre tank Filtered system $1,500	None None $0
8	Tank Filter Price	10,000 litre tank Filtered system $3,000	5,000 litre tank None $0	None None $0

Block 8				
Choice task	**Attributes**	**Option1**	**Option2**	**Base case**
1	Tank Filter Price	5,000 litre tank None $0	10,000 litre tank Non-filtered system $1,500	None None $0
2	Tank Filter Price	5,000 litre tank Non-filtered system $1,500	None Filtered system $3,000	None None $0
3	Tank Filter Price	10,000 litre tank Non-filtered system $3,000	10,000 litre tank None $3,000	None None $0
4	Tank Filter Price	5,000 litre tank Filtered system $1,500	5,000 litre tank Non-filtered system $0	None None $0
5	Tank Filter Price	None Filtered system $0	5,000 litre tank Filtered system $1,500	None None $0
6	Tank Filter Price	10,000 litre tank None $3,000	None Non-filtered system $3,000	None None $0
7	Tank Filter Price	10,000 litre tank Non-filtered system $1,500	5,000 litre tank Non-filtered system $1,500	None None $0
8	Tank Filter Price	5,000 litre tank Non-filtered system $0	None Filtered system $0	None None $0

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