Fall 8-31-2018

Potable Water Reuse in Albuquerque, NM: A Large Scale Community Survey to Understand Public Perceptions and the Impact of Educational Materials on Acceptance

Lauren Nicole Distler
University of New Mexico

Lauren Nicole Distler
Candidate

Community and Regional Planning
Department

Water Resources
Department

This thesis is approved, and it is acceptable in quality and form for publication:

Approved by the Thesis Committee:

Caroline Scruggs, Chairperson

John Fleck

Andrew Schuler

POTABLE WATER REUSE IN ALBUQUERQUE, NM: A LARGE SCALE COMMUNITY SURVEY TO UNDERSTAND PUBLIC PERCEPTIONS AND THE IMPACT OF EDUCATIONAL MATERIALS ON ACCEPTANCE

BY

LAUREN NICOLE DISTLER

BACHELOR OF SCIENCE, GENERAL ENGINEERING,
JAMES MADISON UNIVERSITY, 2015

THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degrees of

Master of Community and Regional Planning
and
Master of Water Resources

The University of New Mexico
Albuquerque, New Mexico

December 2018

DEDICATION

For Maurice and Kait. Thank you for everything.

ACKNOWLEDGEMENTS

Gratitude is extended to the UNM Center for Water and the Environment and the Centers for Research Excellence in Science and Technology (CREST) program at the National Science Foundation (NSF) for the funding to pursue this research. This material is based upon work supported by the NSF under Grant Number 1345169. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the NSF.

Thank you to Dr. Caroline Scruggs, the most supportive advisor I could have ever asked for. Thanks to Dr. Jennifer Thacher for her intellectual contributions to this work throughout the survey design, administration, and analysis processes; and to Katherine Yuhas at the Albuquerque Bernalillo County Water Utility Authority for her interest and support in this project. Many thanks to committee members John Fleck and Dr. Andrew Schuler for their contributions. Finally, thank you to the following UNM affiliates whose assistance on this project was essential to its completion (in alphabetical order): Maurice Cruz, Corinne Fox, Carlos Gomez, Jason Herman, Alyssa Latuchie, Meagan Oldham, Tonya Rintala, and Kellin Rumsey.

POTABLE WATER REUSE IN ALBUQUERQUE, NM: A LARGE SCALE COMMUNITY SURVEY TO UNDERSTAND PUBLIC PERCEPTIONS AND THE IMPACT OF EDUCATIONAL MATERIALS ON ACCEPTANCE

by

Lauren Nicole Distler

B.S., General Engineering, James Madison University, 2015
Master of Community and Regional Planning, University of New Mexico, 2018
Master of Water Resources, University of New Mexico, 2018

ABSTRACT

In New Mexico and much of the American Southwest, ensuring clean, reliable, and sustainable drinking water supplies is one of the biggest existing planning challenges. One option to create more diverse and reliable water supplies is potable water reuse, though projects of this kind have not been widely implemented. This is largely due to negative public perceptions of the practice. There are two types of potable water reuse: indirect and direct potable reuse (IPR and DPR, respectively). The research described in this thesis involves the design and implementation of a large-scale survey administered to a sample of 4,000 water utility customers in Albuquerque, NM, with the aim of examining public acceptance of potable water reuse and whether different types of educational materials have an effect on acceptance. The educational materials tested were designed around the following topics, which have previously been found to motivate acceptance of water reuse: 1) water scarcity and reliability of supplies, 2) the environmental benefits of water reuse, and 3) the urban water cycle and current reuse practices. Our survey response rate was 46% (n=1831). Fifty-four percent of respondents were willing to accept IPR, compared to 47% for DPR. The educational materials provided did not have a statistically significant impact on level of acceptance, though a non-trivial positive effect on predicted acceptance levels was observed. Other survey questions examined trust in various entities, water habits at home, and opinions on topics related to water scarcity and climate change. Compared to previous water reuse surveys conducted on coastal populations, Albuquerque residents placed their trust in similar entities, but appeared to be more aware of water shortage and conservation, and generally more accepting of potable water reuse. Water planners in New Mexico and other arid inland regions may be interested in the results of this research when considering design of public outreach and education programs related to potable water reuse, the feasibility of reuse for their communities, and/or conducting a public acceptance survey themselves.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ABCWUA - Albuquerque Bernalillo County Water Utility Authority

ACS – American Community Survey

BRM – Business Reply Mail

DPR – Direct Potable Reuse

GWRS – Groundwater Replenishment System

IPR – Indirect Potable Reuse

MGD – Million gallons per day

NPOs – Non-Profit Organizations

NSF – National Science Foundation

OCWD – Orange County Water District

PA – Project Assistant

USEPA – United States Environmental Protection Agency

WRF – Water Research Foundation

WRRF – Water Reuse Research Foundation

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

One of the most critical planning challenges in the American Southwest is ensuring clean and reliable water supplies for the future. Climate change is expected to cause more frequent drought, more variable rainfall, and overall less reliable water supplies in the region (Brookshire, Gupta, & Matthews, 2013). The Albuquerque Bernalillo County Water Utility Authority (ABCWUA) in Albuquerque, New Mexico, which provides water to over 600,000 residents, has already begun planning for a future with significantly less water. One option currently being considered is potable reuse of wastewater (ABCWUA, 2016). There are two types of potable water reuse: Direct Potable Reuse (DPR) and Indirect Potable Reuse (IPR). Both DPR and IPR use advanced purification technologies to purify effluent from the wastewater treatment plant to drinking water quality or better. DPR sends the purified water to the drinking water treatment plant, where it is typically blended with native sources before treatment and distribution to water utility customers. IPR differs from DPR in that the purified water is first directed to an aquifer or reservoir where it spends time in the environment before being withdrawn for treatment at the drinking water treatment plant and distribution (Chan, 2014). Figure 1, below, shows the difference between DPR and IPR.

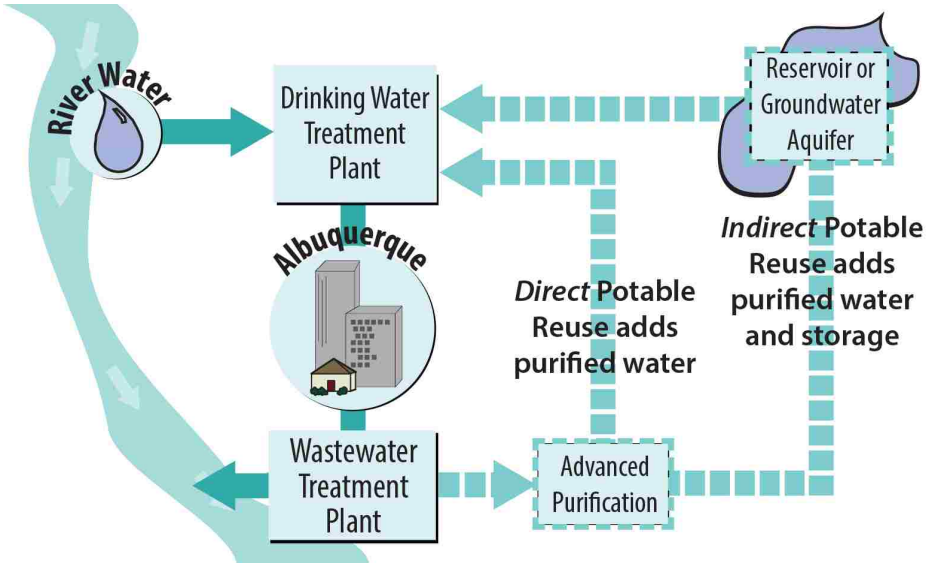


Figure 1: Direct and Indirect Potable Reuse; two reuse scenarios in Albuquerque, NM

Advanced purification technology used in IPR and DPR is feasible on a large scale, and IPR has been implemented in many water-scarce regions (Tchobanoglous, Leverenz, Nellor, & Crook, 2011). However, communities and regulators have been slower to accept DPR projects.

1.1.1 EXAMPLES OF POTABLE REUSE PROJECTS

As previously mentioned, the key distinction between IPR and DPR is the presence of an environmental storage buffer between advanced purification and treatment at the drinking water treatment plant. IPR and DPR facilities can be configured in many different ways. One example of IPR in the United States is the groundwater replenishment system (GWRS) in the Orange County Water District (OCWD) in California. Operational since early 2008, it is the largest advanced purification system for potable reuse in the world. The GWRS takes wastewater effluent that would typically be discharged to the Pacific Ocean and purifies it to drinking water quality or better before injecting it into the groundwater basin in order to combat saltwater intrusion (Tchobanoglous et al., 2011). According to the OCWD website, the system is currently capable of producing up to 100 million gallons per day (MGD) of fresh drinking water for California residents (Orange County Water District, n.d.). The performance and effectiveness of the facility has been proven, making the GWRS a good benchmark for comparison of water quality for other potable reuse projects (Tchobanoglous et al., 2011). Conceptually, the GWRS differs from a typical DPR system by the inclusion of the environmental storage buffer. Many IPR projects in the US and around the world follow a similar treatment scheme to the GWRS (Gerrity, Pecson, Trussell, & Trussell, 2013).

Generally, communities considering the adoption of DPR face severe water shortages or population surges, and have limited options for additional supply; and in some cases IPR is not an option due to the lack of a suitable environmental buffer (Scruggs & Thomson, 2017). The first DPR facility opened in Windhoek, Namibia, in 1968, and has since been operational with “no reports of significant adverse health impacts” (Crook, 2010). In this scenario, reuse water is blended directly into distribution system for the potable water supply. The facility was later updated and the capacity was expanded in 1996 in order to meet the demands of a growing population (Haarhoff & der Merwe, 1996). Since the

Windhoek plant was built, Texas has pioneered the first few DPR projects in the US, with one operational plant in Big Spring, and several others that either operated on a temporary basis or are in the planning stages. Another DPR project is currently being constructed in Cloudcroft, New Mexico, a small mountain resort town that experiences population surges during weekends and holidays, which strains the water supply (Corum, 2015). The configuration for the Cloudcroft project is very similar to the GWRS, except that the purified water is blended with water from native sources and is treated again before distribution. Though the project was designed as IPR, it can also be considered DPR because the water is not stored in an environmental buffer (Tchobanoglous et al., 2011).

Many communities in arid areas may need to begin considering DPR as an option to supplement their water supplies, especially communities that are not located in close proximity to an adequate environmental buffer for IPR or a high-salinity water source for desalinization. Though DPR is slowly becoming more accepted, apprehension about implementation can be linked to a complicated mix of social, economic, regulatory, and technical challenges. As will be discussed in the next few sections, negative public perceptions and attitudes toward potable reuse can hinder and even prevent the implementation of water reuse projects. In fact, public perceptions and attitudes surrounding reuse are currently considered the main barrier to implementation (Hurlimann & Dolnicar, 2010; Ormerod & Scott, 2012).

1.1.2 HISTORIC OPPOSITION TO WATER REUSE PROJECTS

Historically, ineffective public communication and outreach strategies and misinformation have contributed to a negative stigma surrounding potable water reuse. The use of pejorative phrases like “toilet to tap” and “sewage beverage” in public dialog also contributed to this negative stigma, leading to the development of citizen opposition campaigns and the ultimate failure of several water reuse projects (Hartley, 2006; Ormerod & Scott, 2012).

In 1994, the city of San Diego, California, proposed an IPR project that added reuse water into the potable water supply. The only reservoir large enough to accommodate the proposed water quantity served the southern section of the city, where the population was

predominantly of color and lower socioeconomic status. Even though the reservoir served much more of the city than this particular section of town, the public saw the water as being of lesser quality, raising questions about potential racial and socioeconomic biases in the plan. The problem went unaddressed, and the proposal was eventually stopped by the City Council (Hartley, 2006). This case shows that inadequate public outreach and education campaigns can contribute to uncertainty and opposition to a project.

Another example of public opposition to potable reuse occurred in 2006, in Toowoomba, Australia. The water supply for the city of Toowoomba was at a critically low level (the local reservoir was at about 20% capacity). City leaders decided to pursue potable water reuse to augment the city's water supply and did not conduct an adequate public education and outreach campaign. The fact that leaders were pursuing an IPR project was released to some members of the public through informal channels. A public opposition group formed and campaigned against the proposal. Residents were invited to vote on a referendum concerning the implementation of IPR as a means to augment the city water supply and a majority of residents voted against the project. The main concern with the proposal was the potential for the project to portray a negative image of Toowoomba, alongside concerns highlighting the lack of trust in the purification technology, and fears surrounding inadequate regulations to protect public health (Dolnicar, Hurlimann, & Nghiem, 2010). This illustrates the large role that public perceptions can have in the successful implementation of water reuse projects, as well as the significant impact that inadequate public outreach and education can have on projects involving water from alternative sources.

1.1.3 OTHER BARRIERS TO IMPLEMENTATION

In the United States, water law in each state takes one of two forms. The first form, prior appropriation, is common in the Western US where water has historically been scarce. This form allows for water to be allocated to users during times of shortage, based on the time in which the water was first put to use and the right to water was bestowed. This is a legal principle or maxim usually stated as "first in time, first in right". The second form of water law is the riparian doctrine, which is generally the case for Eastern states. The

riparian doctrine bases the right to use water on proximity of the land to the water source (National Research Council, 2012; Utton Transboundary Resources Center, 2015). In the case of New Mexico and much of the Southwest, prior appropriation complicates the practice of water reuse. Compacts between states require that a certain amount of water be delivered to downstream users, based on the amount of water allocated to those users. In order for potable water reuse to be a viable option on a large scale, the downstream requirements must be consistently met and the utility implementing water reuse must own the water rights to the water being reused (Scruggs & Thomson, 2017).

Another regulatory barrier to implementation is the lack of individual state regulation for potable reuse. Technologies not regulated by the government can lead to uncertainty and distrust in the public eye (Tchobanoglous et al., 2011). States currently practicing reuse have evaluated projects on a case-by-case basis, with no overarching criteria in place. California is currently in the process of determining the feasibility of these regulations and criteria, and some have argued for the development of national standards for reuse (Tchobanoglous et al., 2011). By developing regulations, public uncertainty associated with water reuse could be minimized, and the credibility of water reuse projects could be improved (National Research Council, 2012). Scruggs and Thomson (2017) describe additional challenges to implementing potable water reuse in the inland arid southwest.

1.1.4 SIGNIFICANCE OF THIS STUDY

The main objective of the present study is to understand attitudes toward and perceptions of potable water reuse in a medium-sized arid inland community. Such a study will be unique in the literature to date. The research also aims to determine whether providing educational materials on topics related to water reuse and the environment impacts the level of acceptance of two different types of potable water reuse (IPR and DPR). The results of this study will be useful to water planners and engineers in the development of community outreach, communication, and education programs related to potable water reuse projects.

Beyond the analyses conducted for this research, the data collected using our survey instrument includes information on the opinions of ABCWUA customers on other water related and environmental topics. The data will be made publicly available for further

assessment and research, contributing to the body of knowledge on public perceptions of climate change, water reuse, and related topics.

1.2 PREVIOUS RESEARCH ON PUBLIC ACCEPTANCE OF WATER REUSE

Several studies and surveys have been conducted to determine general levels of acceptance of both potable and non-potable wastewater reuse, as well as the social concerns that fuel public opposition (Dolnicar & Hurlimann, 2011; Hartley, 2006; Ishii, Boyer, Cornwell, & Via, 2015; Macpherson & Snyder, 2013; Ormerod & Scott, 2012). Research shows that the information the public receives during planning and implementation, and the sources from which that information comes, are vitally important (Dolnicar & Hurlimann, 2011).

1.2.1 THE ROLE OF INFORMATION

Given the impact that information can have on acceptance, it is important to consider the content of educational materials provided about a project. Public distrust in treatment technologies is a common reason for opposition to water reuse (Millan, Tennyson, & Snyder, 2015). One survey found that the likelihood of use for recycled water increases significantly when participants are provided with definitions and schematics about associated treatment processes (Dolnicar et al., 2010). For policy makers, these results imply that providing factual technical information to the public increases levels of support for water reuse projects, as opposed to the use of persuasive campaigns (Dolnicar et al., 2010; Ishii et al., 2015).

In arid areas, survey results have shown that residents are aware of water shortages, but are relatively unaware of the urban water cycle – including the source of drinking water and what happens to it after use (Gu et al., 2015). Therefore, providing information about how the urban water cycle works and reinforcing the idea that all water has been used before may be beneficial in increasing public acceptance of reuse (Macpherson and Snyder, 2013). In explaining reuse scenarios, it is important to focus on the quality of the water rather than its history (Macpherson & Slovic, 2011).

The words used to communicate ideas also greatly impact perceptions of reuse. Effective educational materials should be “simple enough to understand, but technical enough to trust”. (Macpherson & Slovic, 2011) Specifically, research has been conducted on the use

of proper "water vocabulary" to use in educating the public on water reuse projects. For example, using a descriptive word for water like "pure" to describe reuse water is more beneficial toward public understanding than using words like "wastewater" or "sewage", which are typically used in the water and wastewater industry when talking about reuse. (Macpherson & Slovic, 2011; Millan et al., 2015) Overall, these studies, which were funded by the Water Reuse Research Foundation (WRRF), found that using consistent and straightforward terminology and providing the proper information to alleviate misconceptions aids in increasing acceptance of reuse projects.

1.2.2 TRUST IN INSTITUTIONS

No matter how straightforward the information provided, uncertainty can be introduced if the public does not trust the institution, entity, or individual providing the information. Collectively, the literature suggests that there is generally a low level of trust in government officials, politicians, and the media, and a higher level of trust in researchers, public health professionals, and water utility representatives (Fielding, Gardner, Leviston, & Price, 2015; Hartley, 2006; Millan et al., 2015; Ormerod & Scott, 2012). Trust is built over time, and those planning water reuse projects should work to ensure that the information about a project that is distributed to the public is coming from entities the public trusts (Ormerod & Scott, 2012). The quality, source, and proper communication of information are all important factors in gaining acceptance of reuse.

1.2.3 PSYCHOLOGY OF NEGATIVE PERCEPTIONS

There have been several surveys conducted to investigate the psychological aspects that impact willingness to drink recycled water. The term "yuck factor" has become prominent in wastewater reuse psychology literature. It refers to the impact that disgust has on acceptance of reuse, and stems from a fear of contamination or contagion (Duong & Saphores, 2015; Ormerod, 2016). One study investigated the psychology of decision-making related to water reclamation by examining the results of attitudinal data collected by two different surveys. In discussing those opposed to reuse, the study found that a portion of respondents indicating opposition to reuse oppose it on principle – that no amount of information would change their mind. Aside from implementing potable reuse without telling the public, they argue that the alternative is to wait for water shortages to become so severe that necessity or costs eventually inconvenience people into acceptance

(Rozin, Haddad, Nemeroff, & Slovic, 2015). Evidence from other sources in the literature suggests that these psychological barriers can be overcome with education and providing communities with information from trusted sources. As discussed in Section 1.2.1, it has been discovered that providing the public with information about the production process increases the likelihood of acceptance (Dolnicar et al., 2010). Others have argued that public perceptions related to potable water reuse are much more complex than simple revulsion, and as discussed in the previous section, have suggested that the community context in which the water reuse project is proposed is the more important factor in understanding public acceptance (Ormerod & Scott, 2012).

1.2.4 THE IMPORTANCE OF COMMUNITY CONTEXT

In order to minimize opposition to water reuse projects, water managers should carefully consider the context of the community in which reuse is being proposed (Hurlimann & Dolnicar, 2010). Though scarcity and the need for reliable water supplies is one of the main arguments for water reuse, it should not be relied upon completely to gain public acceptance (Millan et al., 2015). Much of the existing literature investigates water infrastructure projects or water reuse very generally, and relatively few public perception surveys related to acceptance of potable water reuse options have been conducted by academic researchers.

One such study was recently conducted, involving an online survey in four US cities, and found that between 50 and 60% of respondents were in favor of potable water reuse; however, it should be noted that there may have been a self-selection bias and the samples likely were not representative. The survey was conducted online, and the study used a survey sampling service. Two information treatments were tested, each including background information on drinking water in the US and an introduction to potable water reuse, and a varying degree of information regarding national drinking water regulations. About 400 responses were obtained for each city. The study concluded that city and information treatment did not have a significant effect on support for potable water reuse, but identified “trustworthiness of utilities, potential improvements over the status quo, and community-specific drivers that necessitate the use of purified water in a given

setting" as areas that should be addressed when communicating about DPR with the public. (Ishii et al., 2015)

Public acceptance research for potable water reuse has not been done in an inland community of Albuquerque's size. To date, most research related to potable reuse has occurred in large US coastal communities or in Australia (Leverenz, Tchobanoglous, & Asano, 2011). Contextual differences such as climate, location, and history of water scarcity may impact the level of acceptance of reuse (Garcia-Cuerva, Berglund, & Binder, 2016). Ormerod and Scott (2012) demonstrate that "potable reuse is a politicized issue, where expressed concerns reflect social values more complicated than simple revulsion," and that individual perceptions are shaped by local context. In addition to perceptions of water scarcity and climate conditions, the local context surrounding a water reuse project includes the authorities and institutions that initiate discussions about water reuse, public trust in those authorities, and how public outreach and communication is conducted. Local context is different in situations where public conversations about potable reuse have not yet started, and additional research is required to determine optimal approaches for introducing potable reuse in this context.

Lastly, a study by Millan, Tennyson, and Snyder (2015) outlines a model communication plan for fostering acceptance of potable reuse, including recommendations on reaching out to specific demographic groups that may be less likely to accept potable reuse. The study also discusses the importance of reinforcing the value of potable reuse for the community and ensuring that the appropriate stakeholders from the community are involved and provided with correct and consistent information.

1.2.5 TYPES OF EDUCATIONAL INFORMATION THAT MOTIVATE ACCEPTANCE

Researchers have studied the effects of educational materials on public acceptance of water reuse and found that different types of knowledge and information affect attitudes toward water reuse. A small, but groundbreaking, study in Denver in 1985 tested the effects of education on public acceptance of potable water reuse (Lohman, 1987). The researchers had previously conducted a water reuse survey in 1982, where they recruited

participants through random digit dialing by telephone; for the 1985 study, they recruited from the pool of 1982 survey participants to form a non-representative experimental panel of 71 willing participants. Participants were divided into three groups and received either: (1) no information about reuse, (2) an information packet about water reuse in general and the Denver Water Department's "potable wastewater reuse" demonstration plant, or (3) the information packet and a tour of the demonstration plant. Following the educational exposures, participants were asked how they would feel about drinking reuse water (choice categories were: "minds a lot", "minds a little", "doesn't mind", and "doesn't know"). Of those who received the plant tour, the vast majority answered "doesn't mind", with a small percentage answering "minds a little". The majority of those in the other two groups (those provided reading materials and those receiving no information) answered either "doesn't mind" or "minds a little". Furthermore, 23% of the group receiving no information answered "minds a lot", compared to 12% of the group that was provided reading materials. Clearly, educational information, especially in the form of a plant tour, increased acceptance of potable water reuse.

Following up on Lohman's (1987) findings, Dolnicar et al. (2010) surveyed 1000 Australians, who were recruited using an "Australian permission-based research-only internet panel" (p. 1289), about their acceptance of water reuse. A focus of the research was to test the usefulness to an educational campaign of a visually appealing, easy-to-understand schematic that showed how reuse water is produced, with the idea that the schematic would be less burdensome for people to understand and digest compared to a plant tour or educational information packets. Their respondents' "stated likelihood of use" increased significantly when the detailed process information was provided; however it should be noted that the response rate was quite low.

Macpherson and Slovic (2011) found that the public is more accepting of potable water reuse when provided with education about the water cycle, treatment technologies, and safety of the reuse water. They suggested that lack of knowledge about water quality and treatment is the primary reason for public opposition to water reuse. Macpherson and Snyder (2013) further probed these ideas by specifically testing whether public

acceptance of potable water reuse is influenced by knowledge about the urban water cycle and the fact that all water on earth has been used and reused. They conducted research with participants from the US and Australia, including: (1) eight 2-hour focus groups with about 10 people per group who were recruited by phone from purchased random residential list samples, and (2) an approximately 30-minute online survey of 651 people who were recruited using a "combination of random selection and 'opt-in' methodology" (Macpherson & Snyder, 2013). Along with other information and materials, four water reuse scenarios were graphically presented to all participants, including: (1) unplanned potable water reuse (explained as "current practice"), where an upstream community discharges treated wastewater into a river or stream that is the source of drinking water for a downstream community, (2) IPR where a surface reservoir is used to store purified reuse water, (3) IPR where the purified reuse water is pumped upstream of the community of origin's water treatment plant, and (4) the most extreme form of DPR where the purified reuse water is directed back into the community's drinking water distribution system. Participants were told that water would meet or exceed drinking water standards in all scenarios, and specific treatment technologies were not specified. Further, positive, non-stigmatizing terminology as recommended by Macpherson and Slovic (2011) was used in the focus group and survey materials. Results showed that when participants were made aware that the drinking water source in the "current practice" scenario contained wastewater treatment plant effluent and agricultural runoff, most preferred the other three scenarios; in fact, 23% and 28% of the Australian and US survey participants, respectively, preferred DPR (scenario 4) over all other scenarios.

A study by Millan, Tennyson, & Snyder (2015) found that increasing public knowledge of various topics was key for acceptance of potable reuse. These topics included the urban water cycle and the potential environmental and community benefits of potable reuse. Overall, the literature suggests that different types of knowledge affect attitudes toward water reuse (Dolnicar et al., 2010; Lohman, 1987; Macpherson & Slovic, 2011). Consequently, three sets of educational materials were developed for use in the survey. The first set focused on basic facts from the EPA (USEPA, 2012) and the National

Research Council (National Research Council, 2012) on water scarcity and the need for supply reliability, the second discussed the environmental benefits of water reuse (National Research Council, 2012; USEPA, 2012), since support for water reuse is linked to concern for the environment (Jansen, Stenstrom, & De Koning, 2007; Macpherson & Snyder, 2013; Russell & Hampton, 2006; Stoutenborough & Vedlitz, 2014), and the third set described differences between the natural water cycle and the urban water cycle, since improving this understanding has been linked to increased acceptance (Macpherson & Snyder, 2013).

1.3 RESEARCH QUESTIONS AND HYPOTHESES

Though this survey will collect data on a variety of water-related topics, the primary objective of this study is to answer the following research questions, and to test the following hypotheses:

Q1: Does the provision of educational materials increase acceptance of reuse?

- H1a: Providing information on water scarcity and the need for reliable supplies will increase acceptance of water reuse scenarios compared to the control group (no information).
- H1b: Providing information on the environmental benefits of reuse will increase acceptance of water reuse scenarios compared to the control group (no information).
- H1c: Providing information on the urban water cycle and de-facto reuse will increase acceptance of water reuse scenarios compared to the control group (no information).

Q2: How does acceptance of reuse vary by reuse scenario?

- H2: IPR will be accepted at a higher rate than DPR.

Q3: How does acceptance of reuse vary by demographic characteristics?

- H3a: Women will be less likely to accept both water reuse scenarios.
- H3b: Those who have obtained a higher level of education (Bachelors through PhD) will be more likely to accept both water reuse scenarios.

CHAPTER 2: METHODS

The initial draft of the survey was developed based on a review of the water reuse survey literature, and an administration plan was developed based on survey design principles proven effective in obtaining an adequate response rate. (Dillman, Smyth, & Christian, 2014; Thacher et al., 2011) The survey instrument was refined using a series of focus groups and debriefing sessions. Throughout the focus groups and debriefing sessions, the language and graphics were simplified, and the amount of material covered by the survey was decreased in order to improve clarity. Once the survey instrument was refined, a pretest was conducted with 200 potential respondents to test the survey instrument and materials, as well as the administration plan and timeline. Finally, the main survey was sent to 4,000 ABCWUA customers through the mail, with the option to respond online. Responses were entered into Survey Monkey in the months following the administration of the survey. Statistical analyses were conducted in R-Studio, an open-source software, and most plots and other simple calculations were completed using Microsoft Excel. This yielded the final results of the survey. Figure 2 on the next page briefly outlines the methodology for the design, development, administration, and analysis of the survey instrument and associated data, and each of the steps is described in detail in the sections that follow. It should also be noted that the draft survey instrument was revised and refined throughout the steps outlined in Figure 2.

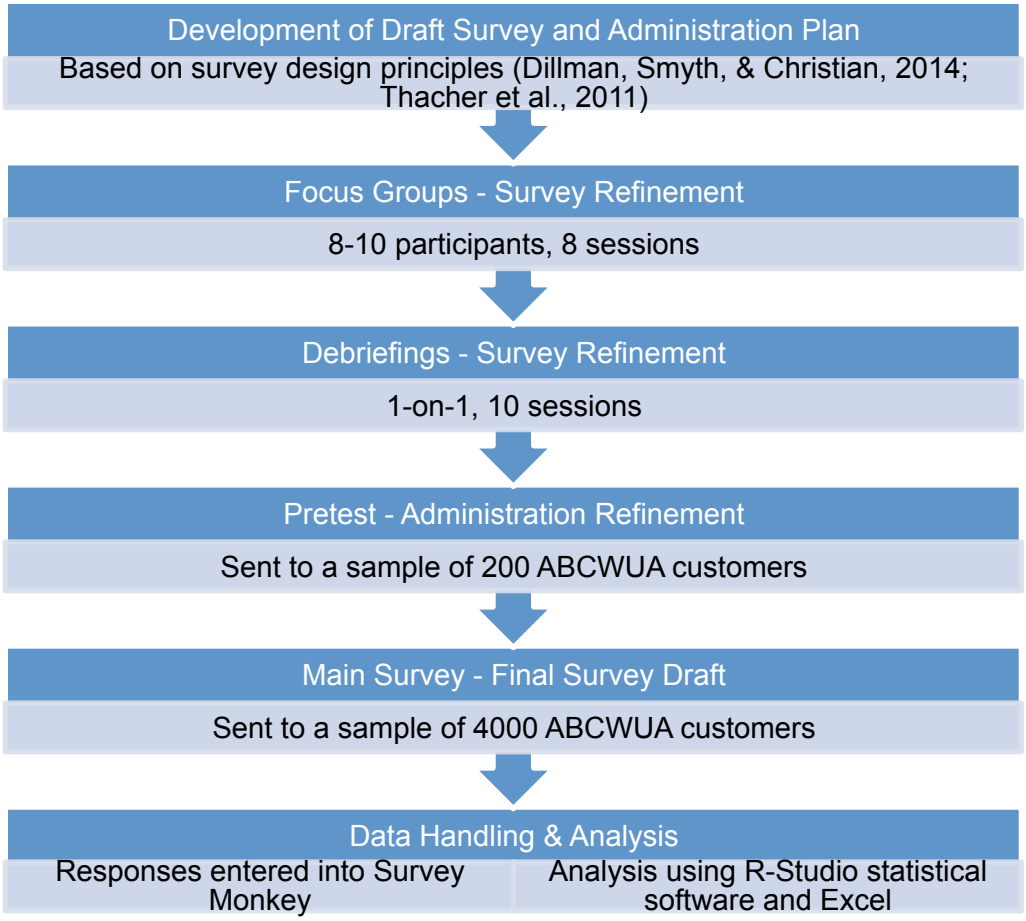


Figure 2: Survey development and administration process outline

2.1 INITIAL SURVEY DESIGN AND REFINEMENT

2.1.1 DESIGN OF INITIAL DRAFT SURVEY

Recommendations were compiled from both the peer-reviewed and grey[1] literatures regarding the types of information to include in a survey on public perception of and attitudes toward potable water reuse. Initially, the survey was planned to include visual and factual information about the technologies used, flow diagrams of the treatment schemes, and cost differences among treatment options. In addition, the survey would ask questions about four different scenarios of potable reuse. It was anticipated that the combination of these recommendations from previous studies would create a survey

[1] Grey literature here refers to non-scholarly research produced by practitioners in the field of water reuse.

instrument that would be easy for the public to understand and capable of revealing public attitudes and preferences related to potable water reuse.

2.1.2 DESIGN OF EDUCATIONAL MATERIALS

Based on the findings from previous research on public perceptions of water reuse described in the previous chapter, three sets of educational materials were designed in order to determine the impact, if any, on acceptance of two potable reuse scenarios. The topics chosen for the educational materials seemed to motivate acceptance of reuse in previous research. The materials were based on the following topics:

1) Water scarcity and reliability of supplies,
2) The environmental benefits of wastewater reuse,
3) The urban water cycle and current (de-facto) reuse practices.

Four versions of the survey instrument were created. The first version served as the control group and contained limited educational information. The other three versions provided respondents with one of the three educational materials listed above. The four versions differed only in the type of educational information (or lack thereof), which was contained on one page (page 5) of the 15-page survey. The paper version of the survey, as well as each of the educational materials, was designed in Adobe Illustrator. The three sets of educational materials are shown in Appendix C, at the end of the survey (pages 91-93 of this document).

2.1.3 FOCUS GROUPS

Focus groups provide critical information for identifying attributes for inclusion in a survey and testing prototypes of survey questions (Krueger & Casey, 2000; Thacher et al., 2011). To inform the design of the survey instrument, eight 90-minute focus groups were conducted with members of the community. Seven to ten participants is considered ideal, so an attempt was made to recruit ten participants per group in order to leave room for no-shows (Thacher et al., 2011). Because the survey sample was to be drawn from the ABCWUA's customer list, focus group participation was limited to those who were water utility customers and at least 18 years of age. Participants were recruited through posted flyers, Craig's List, various listservs, community newsletters, and community

social media (e.g., NextDoor). Participants were offered a $30 Target gift card plus refreshments as an incentive for their time and participation. Focus group sessions were held in a variety of familiar and accessible locations (e.g., community centers, public libraries, University of New Mexico classrooms) to promote broad participation. Participants were given booklets containing educational materials and potential survey questions with the goal of having participants evaluate the effectiveness of the provided materials for helping inland residents of arid communities make informed decisions about potable reuse. Participants identified the materials most useful to them, problems with wording, content, or structure, and any additional information needs. Patterns were identified in perceptions of the survey materials, which resulted in the redesign of survey questions, graphics, layout, and a sizeable reduction in the amount of content included.

2.1.4 DEBRIEFING SESSIONS

Mid-way through the focus groups and at the completion of the focus groups, the survey drafts were tested on individual members of the population (ABCWUA customers) in a series of survey debriefing sessions. Debriefings allow researchers to determine if questions are being interpreted as intended, the time required to take the survey, and any potential problems in completing the survey (Dillman et al., 2014; Thacher et al., 2011). A total of ten participants were recruited in the same manner as described for the focus groups to participate in 60-90 minutes sessions at a location of the participant's choice. The survey instrument was further refined throughout the ten sessions.

2.2 FINAL SURVEY DESIGN

The final version of the paper survey is included as Appendix C, which contains all figures and text described below. The survey begins by asking a series of questions in tabular format to gauge the respondent's level of concern for water supply issues, compared to other issues in the community. A 5-point unipolar ordinal scale was used for these questions (Dillman et al., 2014). The issues of concern (crime, amount paid on local taxes, etc.) were based on previous research (e.g., Millan et al., 2015) and the researchers' knowledge of local concerns. Next, respondents were asked several questions related to the Albuquerque/Bernalillo County water supply, climate change, water scarcity, and water habits at home. Once the questions pertaining to home water habits were answered, respondents were provided with one of four potential educational

material sets, as discussed in Section 2.1.2. Again, the set of educational materials included in each survey was the only point of difference among the four versions. The four versions of the survey (based on type of educational information) are repeated below for convenience. Each version will now be referred to as the abbreviated name listed next to it in parentheses.

Version 1: No information provided (Control Group)

Version 2: Water sources and reliable supplies (Water Scarcity)

Version 3: Environmental benefits of reuse (Environmental Benefits)

Version 4: Urban water cycle (Urban Water Cycle)

Respondents were then asked two follow up questions; the first asking about level of awareness of water scarcity issues in New Mexico, and the second asking whether or not they had prior knowledge of potable water reuse. Next, DPR was introduced, with a diagram describing the additional steps that would be added to the "Standard Drinking Water Treatment" of a hypothetical community, "Community A". DPR is described below the diagram, and instances of DPR implementation are mentioned. Respondents are then asked about their willingness to drink the city tap water in Community A, using a 5-point bipolar ordinal scale. The next two questions delved into the potential reasons a respondent would or would not be willing to drink the water. Similar to Millan et al. (2015) and Macpherson and Snyder (2013), common reasons for acceptance and/or common concerns are listed as options, with an "Other" category offered last to capture any additional ideas or concerns. Next, IPR was introduced in an identical manner to DPR. The questions following the IPR diagram were the same as they were for DPR, with one additional answer choice to test the effect of the presence of an environmental buffer. The next section reiterated the key difference between DPR and IPR, and asked which type of reuse the respondent would be more willing to accept (i.e., IPR or DPR). "Both types of reuse are equally acceptable to me" and "Neither type of reuse is acceptable to me" were also listed as possible answer choices.

The next question delved into the level of trust that the respondents had in various institutions to provide accurate information on water reuse. A 5-point bipolar ordinal

scale was used to ask about trust in eight entities. Choice categories included "Mostly Distrust", "Somewhat Distrust", "Neutral", "Somewhat Trust", and "Mostly Trust". Finally, a series of nine demographic questions were asked in order to determine how similar the survey respondents were to other ABCWUA customers. Sensitive questions, such as those related to demographics, may cause a respondent to quit the survey before completing it. Placing the most sensitive demographic questions at the end of the survey can prevent respondents from quitting the survey before completion since they have already invested the effort in completing most of the survey (Thacher et al., 2011). The survey concludes with a comment box, allowing respondents to voice any additional concerns they may have about water reuse. Below it, several weblinks and QR codes are provided, with the option of tearing them off the paper survey, for participants who want additional information on drinking water quality standards and advanced purification technologies.

2.3 SURVEY ADMINISTRATION

2.3.1 SAMPLING

Ideally, the survey sample should represent all water users in the area. The Albuquerque Bernalillo County Water Utility Authority (ABCWUA) is the sole provider of water and wastewater services to the greater Albuquerque metropolitan area, serving over 600,000 water users. The ABCWUA has expressed interest in potentially pursuing IPR and DPR projects in the future, and therefore has an interest in determining the best way to approach the subject of reuse with the public. Given the breadth of the ABCWUA's customer base and the need to ensure effective public interaction on these topics, the specific population of interest was current customers of the ABCWUA. It should be noted that it is not known if the ABCWUA customer list is representative of Albuquerque and Bernalillo County residents as a whole. While it is difficult to determine whether the survey sample is representative of Bernalillo County, the geographic and population differences between the county and the ABCWUA service area can be investigated. By using mapping software, the population of those living in Bernalillo County who are not served by ABCWUA was roughly estimated. This was done by comparing the total population of the census tracts that fall within the ABCWUA service area boundary to the population of Bernalillo County as a whole. The total population of Bernalillo County as

estimated by the 2010 Census data is just under 675,000. Approximately 27,000 of these residents fall into census tracts not served by the ABCWUA. These tracts occupy a larger area and are less dense than the tracts in the ABCWUA boundary, and are primarily located closer to the eastern and southern boundaries of Bernalillo County. Setting aside geographic differences between the ABCWUA service area and Bernalillo County, the customer list contains only account holders, or homeowners. This means that most renters (specifically renters who have utilities included as part of their rent paid to a landlord) in the Albuquerque and Bernalillo County area were not likely included in the study. Additionally those who rent are generally younger and possibly of lower economic status, so residents in these groups may be underrepresented by the survey sample.

Using the ABCWUA customer list, and a column of randomized values, four random samples of 50 (N=200, pretest), and four random samples of 1000 (N=4000, main) were selected from over 180,000 customer accounts. Once the samples were created, they were checked to ensure that they were representative of the approximate proportions of customers in each quadrant of the city according to the ABCWUA list. The samples for the pretest and main survey were then split up into two excel workbooks, with a separate sheet for each version of the survey. Data for customer address, zip code, city quadrant (NE, SE, SW, NW) and census block for each participant were retained. When it came time to send out mailings related to the survey, mail to each contact was addressed to "Water Utility Customer" in place of all names in order to ensure that responses remained anonymous.

2.3.2 SURVEY MODE

The U.S. Census Bureau (2014) estimates that approximately 27% of residents living in the Albuquerque metropolitan area either do not own a computer or own a computer without an Internet subscription. In order to most accurately represent the population of interest, the survey was administered via mail, with the option provided to respond online via Survey Monkey. Mail administered surveys can be easily distributed to a random sample of addresses and are generally more cost effective than telephone surveys (Dillman et al., 2014). Additionally, while we were able to obtain customer addresses from the ABCWUA customer list, this list did not contain customer telephone numbers.

Furthermore, research has shown that mail surveys generally achieve higher response rates than other modes provided that they are of reasonable length for the data being collected (Dillman et al., 2014).

2.3.3 SURVEY ADMINISTRATION PLAN AND TIMELINE

Before conducting a large scale mail survey, a pretest should be conducted in order to verify the survey instrument, estimate the response rate for the larger survey, and test the administration procedures (Thacher et al., 2011). For this study, the survey pretest was conducted on a sample of 200 ABCWUA customers, and the main survey was conducted on a random sample of 4,000 customers. A system of five contacts was developed and used for the survey. This system is known as the Tailored Design Method, a set of standard procedures to increase the response rate of mail surveys (Dillman et al., 2014). Each contact included a letter or postcard to the respondent and provided a personalized code that can be used to respond to the survey online. These materials are in Appendix A. A general timeline of the survey administration is as follows:

- Contact 1 – DAY 0 - Letter from ABCWUA with survey introduction
- Contact 2 – DAY 7- First Survey Packet (letter, booklet, stamped return envelope, $2 bill)
- Contact 3 – DAY 14 - Reminder Postcard
- Contact 4 – DAY 28 - Second Survey Packet (letter, booklet, BRM return envelope)
- Contact 5 – DAY 56 - Third Survey Packet (letter, booklet, BRM return envelope)

The pretest was a useful tool to test the efficiency and logistics of the administration timeline. After the pretest, final refinements are made to the survey instrument and administration materials before administering the main survey. The same general timeline was followed for the main survey.

In this survey, Contact 1 was a letter from Katherine Yuhas, Water Resources Division Manager for ABCWUA. In her letter, the survey was introduced, respondents were informed of the importance of their response to the success of the study, and that if they were one of the first 500 customers to respond to the survey, they would be entered into a

raffle to win a rain barrel. Contact 1 went to the entire sample. The letter was printed on an ABCWUA letterhead and sent in an ABCWUA envelope.
Contact 2, sent a week later, was the first survey packet. A letter was included that introduced the UNM researchers, explained the reason for the study, and linked the respondent to the online version of the survey. Printed on the bottom of each letter was a hyperlink to one of the four online survey versions, as well as a personalized 6-digit code to anonymously access the survey. Also included were a $2 bill, survey packet, and stamped return envelope. These practices have been shown to result in a higher response rate (Dillman et al., 2014; Thacher et al., 2011). Contact 2 also went to the entire sample.

Contact 3, a reminder postcard, was sent out a week after contact 2. A note on the card reminded potential respondents of the importance of their response, and the survey weblink and personalized 6-digit code to respond to the online version were again included. Contact 3 also went to the entire sample.

Contacts 4 and 5, the second and third survey packets, were sent several weeks apart and were identical to Contact 2, but the $2 bill was omitted, and the stamped return envelope was replaced with a Business Reply Mail (BRM) envelope. Using BRM envelopes in Contacts 4 and 5 cut down on costs because postage is only paid on the envelopes that are returned. Contacts 4 and 5 were only sent to those who had not yet responded. Responses were tracked using the personalized 6-digit codes on each of the survey packets that was returned or entered online so that the respondent could be removed from the sample mailing list for the next contact. Due to the timeline for the survey and the relative speed of "snail mail", it was not always possible to remove all codes that had responded before the next contact. This resulted in several duplicate responses in the data, and the less complete of the two responses (or most recent, if both were complete) was removed. Figure 3 on the next page is a timeline showing the dates that the main survey contacts were sent out between April and June 2017.

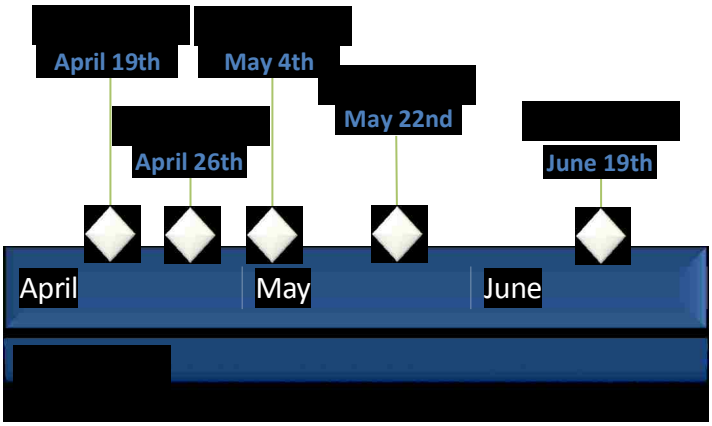


Figure 3: Timeline for administration of main survey

2.3.4 PREPARING THE SURVEY MATERIALS

Listed below are the materials that were used in the survey administration process. With the exception of the ABCWUA envelopes and letterheads, all printed survey materials were ordered from CG Printers, a local print shop in Albuquerque, New Mexico. The ABCWUA envelopes were purchased directly from ABCWUA.

- ABCWUA envelopes and letterheads
- Outgoing envelopes for packets
- Return envelopes
- BRM envelopes
- Letterheads
- Survey Booklets

The quantities ordered of the materials above were based on response rate estimates as outlined in Thacher et al. (2011). The $2 incentives included in Contact 2 were ordered through the University of New Mexico Bursar's office after creating a protocol document and submitting a petty cash request to Grants and Accounting. The bills were delivered to the UNM Cashier's office. They were picked up by the petty cash custodian, transported in locked money bags, and held in a locked safe until supervised stuffing of Contact 2 envelopes with UNM Mailing Systems employees on Day 7 of the survey timeline.

For Contacts 2, 4, & 5, the letters included in the survey packets were each printed with a unique online code to use if taking the online version of the survey, the date the contact was to be sent out, and the weblink to the correct online survey version. This is called "variable data" printing, and the variables (personalized 6 digit code, date, and survey weblink) for each person in the sample were contained in an excel document. Furthermore, these contacts were assembled in a way that increased the likelihood of the respondent seeing all of the contents of the packet when removing them from the envelope. Figure 4 shows the assembly order for Contact 2, 4 and 5, with the exception that Contacts 4 and 5 did not include a $2 bill.

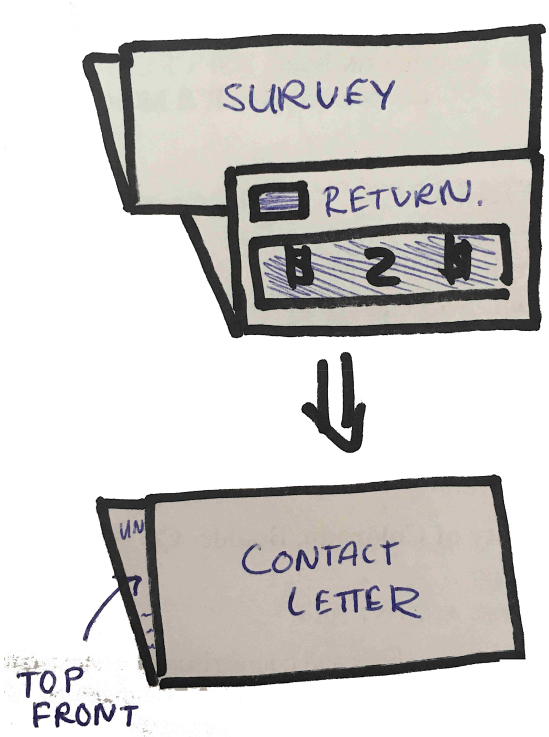


Figure 4: Assembly/stuffing order sketch for Contact 2

The online versions of the survey were created using Survey Monkey. One online version was drafted based on the final paper version of the survey in order to minimize discrepancies between the online and paper versions. This survey was duplicated three times and page 5, the educational materials page, was changed to fit each of the four versions accordingly.

2.4 DATA ENTRY AND ASSEMBLY

Approximately 85% of respondents completed the survey via mail. In order to properly compile the data, each mail response was coded online into Survey Monkey using the manual entry feature by one of four Project Assistants (PAs). Each PA was in charge of a survey version in order to avoid confusion and to cut down on errors. Assistants were given guidelines for entry, including a document with several rules for blank and duplicate responses (see Appendix B), and were encouraged to work in short sessions to avoid fatigue and errors in entry.

On September 5th, 2017, the online surveys were closed for further responses and the last of the mail responses were coded. Once all responses were coded, the data for each of the four survey versions was downloaded from Survey Monkey into Excel format. These files were compiled into a single .csv file for easier handling. Most responses were coded numerically, with, for example, a 0 representing a non-response, a 1 representing "Yes", a 2 representing "No", and a 3 representing "I Don't Know". This is discussed further in Section 2.5.1. Coding responses to numeric values is the best format for importing the data into R, the open source statistical coding software that was used for survey data analysis.

2.5 DATA ANALYSIS

This section will outline the methods used in analyzing the survey data. The data file (.csv) downloaded from Survey Monkey was automatically split into columns by each response option. The method for creating variables, which can be done in either Excel or R, is described using the following example: Consider a survey question with three response options, allowing respondents to only select one. This question would have three columns of data in the original Survey Monkey file associated with it. These three columns would be summed for each row, resulting in a single column of data, containing a value from 0 to 3 (each value representing a different response option or non-response). For questions allowing the selection of more than one response option, the columns were left as-is because there must be multiple binary variables (one for each answer option) associated with these questions in order to analyze them.

2.5.1 SURVEY CODEBOOK

As discussed above, for each question included in the survey, one or more variables must be created in order to analyze the results. One way of keeping track of these variables and their potential values is using a codebook. The following key was used to create the codebook for each variable in the dataset:

```
Variable name
Variable description
Data type (Continuous, Discrete, Nominal, Ordinal)
Item Value, Description
```

For example, Question 1 in the survey asks the respondent to gauge their level of concern with eight different issues in Albuquerque/Bernalillo County. In this case, a variable was created for each issue, and a numeric value from 1-5 represents their level of concern. A non-response would appear as a 0. The entry in the codebook for level of concern with drought/water shortage in the region would appear as follows:

```
DROUGHT_CONCERN
Level of concern with drought
Ordinal
1. Not at all concerned
2. Slightly concerned
3. Moderately concerned
4. Very concerned
5. Extremely concerned
```

For survey questions that allowed for multiple responses, a binary variable was created for each response option, i.e., a value of 1 was given if the respondent chose that option, and a 0 was given if not. In order to assess the results of a multiple response question, each of the binary variables associated with the question must be taken into account. That is, instead of simply counting the number of responses in each category for a single variable, the number of responses for each response option variable must be counted and summed. Coding variables in this way allows for simpler quantitative analysis of

attitudinal data using Excel and statistical software. The codebook for the survey is located in Appendix D. The codebook is also a useful tool to help someone who is not closely associated with this study understand the structure of the dataset.

2.5.2 DATA CLEANING

One of the first steps in assessing the survey data was to clean the data file. Cleaning the data makes it more intuitive to comprehend in .csv form and makes analyses much simpler. Each entry (or row) in the data file is associated with a respondent ID number, and each survey question has one or more variables (or columns) associated with it. If a respondent did not answer a question, the cell was blank or took a value of 0 in the Survey Monkey data file. These blank cells were replaced with the text "NA" in R. This is a standard way to deal with missing data. The data were also cleaned of duplicate responses from the same ID, and the integers for questions with "Yes", "No", and "I don't know" response options were replaced with "Y", "N", and "DK" within the data set. Cleaning the data in this way allowed for simpler data analysis and ensured that arithmetic operations were not performed on nominal variables. In addition to simplifying nominal variables, new variables were created that group several response options for ordinal variables into simplified categories. For example, the demographic question on level of education included eight different (ordered) response options, ranging from "Less than high school" to "Doctorate/Professional degree". In this case, the bottom three categories for education level were grouped into "Low", the middle three categories into "Mid" and the top two categories into "High"; and a new variable, `EDUCATION_CAT`, was created with this organization. Once these changes were made, the cleaned data was exported from R to a new .csv file, which served as the file to work from and use for all future analyses.

2.5.3 ANALYSIS METHODS

In general, single-response questions were all assessed in a similar manner. Using Excel, the frequency of each response option was calculated using the "COUNTIF()" function for each potential value of the variable. These values were tabulated, and the percent breakdown of the response options was calculated. This was done for each single-response survey question asked of respondents. Analysis methods for multiple-response questions differed slightly, as they involved the assessment of several variables. For this

project, the data associated with multiple response questions was assessed in one of three ways: by 1) simply determining the frequency that each response option was selected, 2) determining the percentage of respondents who chose that answer in combination with other answers, or 3) determining the frequency that each response combination was selected. For the first method, one can simply count the number of cells containing a value, as with the single-response questions. The second method uses the frequency for each response option calculated in the first method to determine either the percent of total responses (Freq/Sum(Freq)), or more usefully, the percent of cases or respondents that selected that response option (Freq/ (Total # of Respondents)). Table 1 shows an example of how these would be calculated for one of the multiple response questions from the survey, Question 3. Question 3, which can be viewed in Appendix C, asks respondents about the source(s) of the water that the ABCWUA provides to customers.

Table 1: Example showing how percentage of responses and percent of cases are calculated for a multiple-response survey question

Notes:	*number of 1's in each column*	*Freq/Sum(Freq)*	*Freq/(Total # of Respondents)*
Variable Name	**Freq**	**% of Responses**	**% of Total Cases**
SOURCE_SW	1081	37.8	59.0
SOURCE_GW	1359	47.5	74.2
SOURCE_DK	325	11.4	17.7
SOURCE_OTHER	94	3.3	5.1
Sum(Freq)	2859	100	-

With a total of 1831 respondents, we see that 59% chose surface water either alone or in combination with other answer options.

The third method of assessing multiple response questions involves using a function in R, `"multi.freq.table"`, which was written by an R user and uploaded to an online forum for public use. Once applied to the variables of interest, this function creates categories for each of the possible answer combinations associated with a question. The function then counts the number of respondents that fall into each category, and produces a frequency table of values, which can be exported as a .csv file. This table can be sorted from largest to smallest values in Excel, and the most frequent answer combinations can

be obtained. Continuing the example from above, Table 2 shows an example of output from the `"multi.freq.table"` function in R. The code for this function is available as Appendix E. It should be noted that this code was vetted to ensure that the function performed as intended using a simple data file with a known number of responses in each category.

Table 2: Example output showing frequency of response combinations

	Response Combinations	Freq
1	NA	27
2	SOURCE_SW	120
3	SOURCE_GW	388
4	SOURCE_SW-SOURCE_GW	883
5	SOURCE_DK	301
6	SOURCE_SW-SOURCE_DK	6
7	SOURCE_GW-SOURCE_DK	8
8	SOURCE_SW-SOURCE_GW-SOURCE_DK	4
9	SOURCE_OTHER	11
10	SOURCE_SW-SOURCE_OTHER	5
11	SOURCE_GW-SOURCE_OTHER	12
12	SOURCE_SW-SOURCE_GW-SOURCE_OTHER	60
13	SOURCE_DK-SOURCE_OTHER	2
14	SOURCE_SW-SOURCE_DK-SOURCE_OTHER	0
15	SOURCE_GW-SOURCE_DK-SOURCE_OTHER	1
16	SOURCE_SW-SOURCE_GW-SOURCE_DK-SOURCE_OTHER	3

The sum of the "Freq" column in Table 2 is equal to the total number of survey respondents (n=1831). In this example, we see that the majority of respondents (833) chose both the "Surface Water" and "Groundwater" response options. In the case of Question 3, the third method provides the most useful assessment of the data. However, the first two methods were used in assessing questions where the combinations of answer options were less useful, for example, in determining the most common water conservation measures being practiced at home (Question 7).

In order to cross-examine two or more survey questions, the function `"xtabs"` was used in R. This function creates a frequency or contingency table from cross-classifying factors. An example of how this function is used is shown in the code block below:

```
tab.freq <- xtabs( ~ DPR_WILL + REUSE_AWARE, data =
acceptance)
write.csv(tab.freq, 'reuse_aware.csv')
```

This code produces a contingency table showing the breakdown of willingness to accept categories for DPR (1- “Refuse to Drink”, 2- “Prefer to Avoid”, 3-“Neutral”, 4-“Generally OK”, 5-“Very Willing to Drink”), and the frequency of those who had prior knowledge of reuse and those who did not within each category. Then, the frequency table is written to a .csv file, which for this example contains the data shown in Table 3.

Table 3: Contingency table showing willingness to accept DPR and prior knowledge of reuse

	REUSE_AWARE	
DPR_WILL	N	Y
1	37	65
2	144	254
3	141	238
4	159	459
5	34	190

This data can then be manipulated and used for calculations and plots in Excel. This same procedure can be applied to any of the categorical variables in the survey dataset.

Next, the methods used for the statistical model to explain willingness to accept each of two potable reuse scenarios will be discussed. As previously mentioned, willingness to accept in this survey was measured on an ordinal scale with five categories, or Likert scale. Traditional classification methods (logistic regression, support vector machines, decision trees) are usually designed for deciding between two categories. One possible solution is to partition the Likert scale into “willing to accept” and “unwilling to accept”, but then it is unclear which of these two categories the middle “Neutral” option belongs to, and these analyses can be quite sensitive to the category this portion of respondents is placed in. Although these methods can be extended to handle multiple nominal

categories, they usually fail to account for the ordinal nature of the response variable. The class of Cumulative Link Models (CLMs) are designed to address this problem, particularly the proportional log-odds CLM, which is also referred to as ordered logistic regression (McCullagh, 1980). This model is briefly explained below.

Suppose that there are i ordered categories in which the response (dependent) variable can fall into, and assume that $\boldsymbol{x} = (x_1, x_2, \cdots x_p)$ is a list of p explanatory variables for a certain individual. The i ordered categories of the response variable have probabilities $\pi_1(\boldsymbol{x})$, $\pi_2(\boldsymbol{x})$, ... $\pi_i(\boldsymbol{x})$. In other words, $\pi_i(\boldsymbol{x})$ is the probability that an individual, with explanatory variables $\boldsymbol{x}$, gives a response falling into category i.

Given the following definition: $\gamma_i(\boldsymbol{x}) = \pi_1(x) + \pi_2(\boldsymbol{x}) + \cdots \pi_i(\boldsymbol{x})$, $\gamma_i(\boldsymbol{x})$ is the probability that this same individual falls into category *i,* or any category below it, due to the cumulative nature of the model. For the class of CLMs, the relationship between explanatory variables and the response variable is modeled as: $g\big(\gamma_i(\boldsymbol{x})\big) = \theta_i + \beta_1 x_1 + \beta_2 x_2 + \cdots \beta_p x_p$, where β values represent various regression parameters for each variable, and $g\big(\gamma_i(\boldsymbol{x})\big)$ represents the link function. The following link function is used for the purpose of this analysis, though the link function for CLMs can take several forms:

$$g(\gamma) = \log \frac{\gamma}{1-\gamma}$$

To fit the model to the survey data, the bottom two categories were combined into "Unwilling", "Neutral" was left as the middle category, and the top two categories were combined into "Willing". A model was fit for each scenario, using the following predictor variables. Details on these variables are available in the codebook, Appendix D. In cases where a new version of a variable was created for this analysis, a brief description is included below it in the following list of independent variables:

- **GENDER**
- **AGE**
- **NM_NATIVE ('Y', 'N')**
- **REUSE_AWARE ('Y', 'N')**

- **POLITICAL_GROUPED (‘DEM’, ‘REP’, ‘IND/NONE’, and ‘OTH’)**
  Green and Libertarian affiliated respondents were grouped to create the ‘OTH’ category.
- **EDUCATION_LEVEL (‘High school degree or less’, ‘Some college’, ‘College degree’, ‘Advanced degree’)**
  This variable was created by simplifying the eight education categories included in the EDUCATION variable into the four categories listed above.
- **INCOME_QUANT**
  Discrete variable calculated using the midpoint of each income category on the categorical INCOME variable. The upper bound was used for the lowest income category (‘Less than $14,999’), and the lower bound was used for the highest income category (‘$200,000 or more’).
- **VERSION_BIN (‘TRUE’, ‘FALSE’)**
  Binary variable created by grouping the three survey versions that provided educational materials together into the ‘TRUE’ category, leaving the control group in the ‘FALSE’ category.

The results of these models will be discussed in the next chapter, and the code used in these analyses is provided in Appendix F. Furthermore, since a primary goal of this survey was to determine the effect of educational materials on willingness to accept potable reuse, we also fit the above model using only the presence of educational materials, or the VERSION_BIN variable. This model more or less considers the effect of the educational materials, assuming that all other variables are held constant. After fitting model parameters, the probability that an individual will fall into each category can be estimated. By solving the model equation and logit function for $\gamma_i(\boldsymbol{x})$, the following equation is obtained:

$$\gamma_i(\boldsymbol{x}) = \frac{e^{\theta_i + \beta_1 x_1 + \beta_2 x_2 + \cdots \beta_p x_p}}{1 + e^{\theta_i + \beta_1 x_1 + \beta_2 x_2 + \cdots \beta_p x_p}}$$

For only one variable this simplifies to

$$\gamma_i(\boldsymbol{x}) = \frac{e^{\theta_i + \beta X}}{1 + e^{\theta_i + \beta X}}$$

Using this equation, and the coefficients obtained from the model output, the probability that an individual falls into each category can be calculated, based on whether or not educational materials were received. Since there are only *i = 3* classes ("Unwilling, "Neutral", and "Willing"), the following system of equations can be solved for the other probabilities:

$$\pi_1(\boldsymbol{x}) = \gamma_1(\boldsymbol{x})$$

$$\pi_2(\boldsymbol{x}) = \gamma_2(\boldsymbol{x}) - \pi_1(\boldsymbol{x})$$

$$\pi_3(\boldsymbol{x}) = 1 - \pi_1(\boldsymbol{x}) - \pi_2(\boldsymbol{x})$$

The estimated probability of acceptance for both scenarios, based on the presence of educational materials, as well as the results of the CLMs for IPR and DPR will be discussed in the next chapter.

CHAPTER 3: RESULTS AND DISCUSSION

3.1 PRETEST

The pretest was a useful tool to test the survey administration methods, ensure that respondents answered questions as they were intended, and work out any flaws in the design and administration of the survey. Pretests also generally serve as good predictors of the response rate for the main survey (Thacher et al., 2011). The pretest was sent to 200 ABCWUA customers. With 82 respondents, the response rate for the pretest was 41%. Following the pretest, the formatting of several questions was altered for greater clarity. Overall, there were not many changes made to the survey instrument or the administration process. The codebook and R code for analysis were partially developed and tested at this stage, in order to prepare for the results of the main survey.

3.2 MAIN SURVEY

The response rate for the main survey was about 46%, with a total of 1831 responses. This calculation was done by simply dividing the number of eligible responses by the total number of surveys sent (4000), and does not take into account recipients of unknown eligibility. These are recipients who were not contacted, as the incomplete surveys were returned by the postal service (due to incorrect address, vacant home, or otherwise). The response rate breakdown by version is shown below, in Table 4.

Table 4:Number of responses and response rate breakdown by survey version

Version	N	Response Rate (%)
1 – Control Group	466	46.6%
2 – Water Scarcity	466	46.6%
3 – Environmental Benefits	450	45.0%
4 – Urban Water Cycle	449	44.9%
Total	1831	45.8%

It is estimated by UNM mailing systems that approximately 5% (about 200 surveys) were not delivered to a recipient. A more liberal response rate can by calculated by subtracting these from the total number of surveys sent. With this adjustment, a total response rate of 48.18% is obtained.

The final .csv file exported from R had 1831 observations of 85 variables. The following subsections delve into the results from the main survey. Results are addressed in the

order that the survey questions were asked, and the implications of these results will be discussed. Several of the plots and tables in the following subsections include "NA" values, which represent a non-response or missing data for that question. Countless analyses can be done with this data set, many of which extend beyond the scope of this thesis. Due to the size, utility, and wide applicability of the data set, the .csv file will be made publicly available for further research at the conclusion of this study.

3.2.1 PARTICIPANTS' LEVEL OF CONCERN WITH COMMUNITY ISSUES

The first question in the survey dealt with the respondents' level of concern with water related issues as compared with other issues in the community. The plot below, Figure 5, shows the breakdown of results for this question. The issues are listed in the same order as they appear in the survey question.

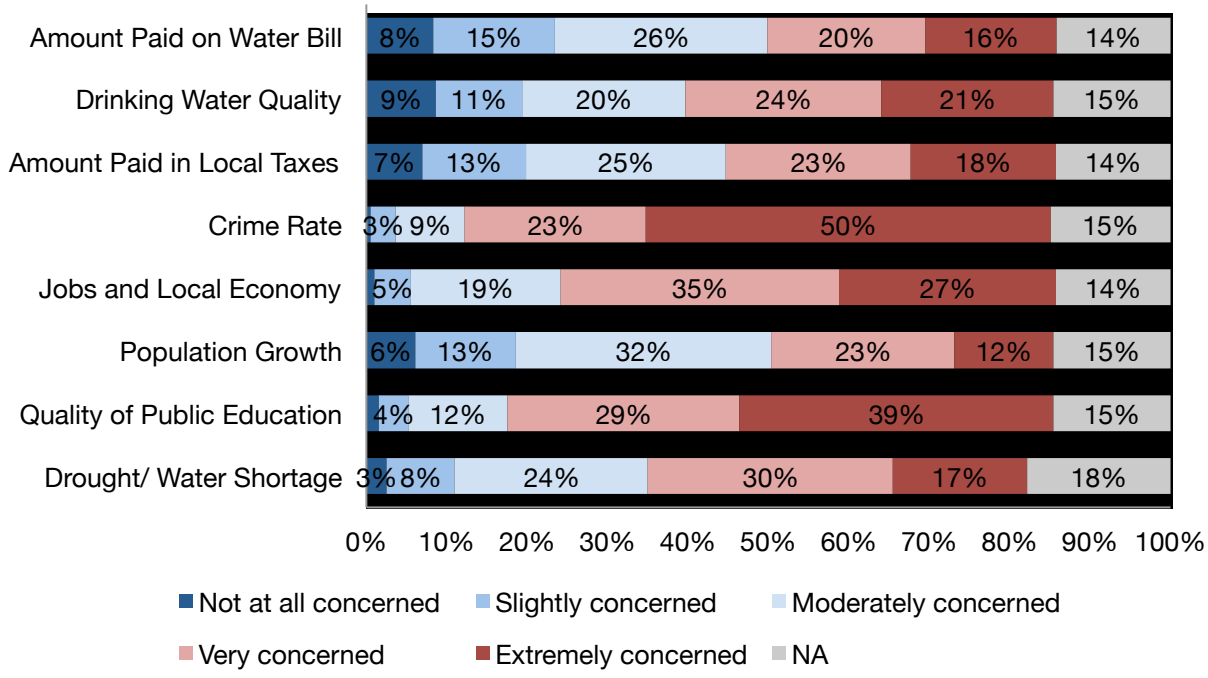


Figure 5: Level of concern with water related issues, compared with other community issues

There is a large percentage of "NA" values where respondents left this question unanswered. This could be due in part to the design of the survey booklet. Respondents could have overlooked this question, as it was on the inside cover of the booklet. Table 5

shows the sum of the "Very/Extremely Concerned" categories for each issue, and the issues are listed by greatest level of concern.

Table 5: Community issues sorted from highest to lowest level of concern

	Total Very/Extremely Concerned
Crime Rate	73%
Quality of Public Education	68%
Jobs and Local Economy	62%
Drought/ Water Shortage	47%
Drinking Water Quality	46%
Amount Paid in Local Taxes	41%
Amount Paid on Water Bill	36%
Population Growth	35%

Results show that the top three issues of concern are the crime rate, quality of public education, and jobs and the local economy, with 73%, 68%, and 62% of respondents indicating that they were "Very" or "Extremely" concerned, respectively. Respondents seemed to be slightly less concerned with water related issues, with 47% and 46% indicating they were "Very" or "Extremely" concerned about drought and water shortage and drinking water quality, respectively. Several of the response options were adapted from a study by Millan et. al. (2015), which found that water issues ranked much higher in level of concern than the results from this survey. This could be due to the time in which the Millan study was conducted – during a statewide drought in California. Respondents to our survey seemed to be most concerned with local issues unrelated to water, including the quality of public education and the crime rate. According to the 2018 Education Week "Quality Counts" national report, which ranks the quality of public education in the United States, New Mexico was ranked next to last. Furthermore, the 2016 FBI Crime in the United States report shows New Mexico has the highest property crime rates per 100,000 people in the country, and the second highest rate for violent crime. While it is difficult to rank states against each other, these rankings may explain some of the concern with these issues that respondents to our survey have indicated.

3.2.2 WATER SUPPLIES AND HOME WATER USE

In this section of the survey, respondents were asked a series of questions about water scarcity, climate change, water sources, and water use at home. Question 2 asked respondents if they believed water was a limited resource in Albuquerque. Eighty-one percent of respondents answered "Yes", 10% answered "No", and 7% answered "I don't know". These results are encouraging, as New Mexico has experienced cyclical drought over the last few centuries, and these conditions are only expected to worsen with the impacts of climate change (Brookshire et al., 2013). Next, question 3 dealt with the source of Albuquerque's water, and allowed each respondent to select more than one answer. Albuquerque incorporates both groundwater and surface water into the water supply. Figure 6 shows the breakdown of the responses. The majority of respondents chose "groundwater and surface water", followed by "groundwater" only. The third most popular option was "I don't know".

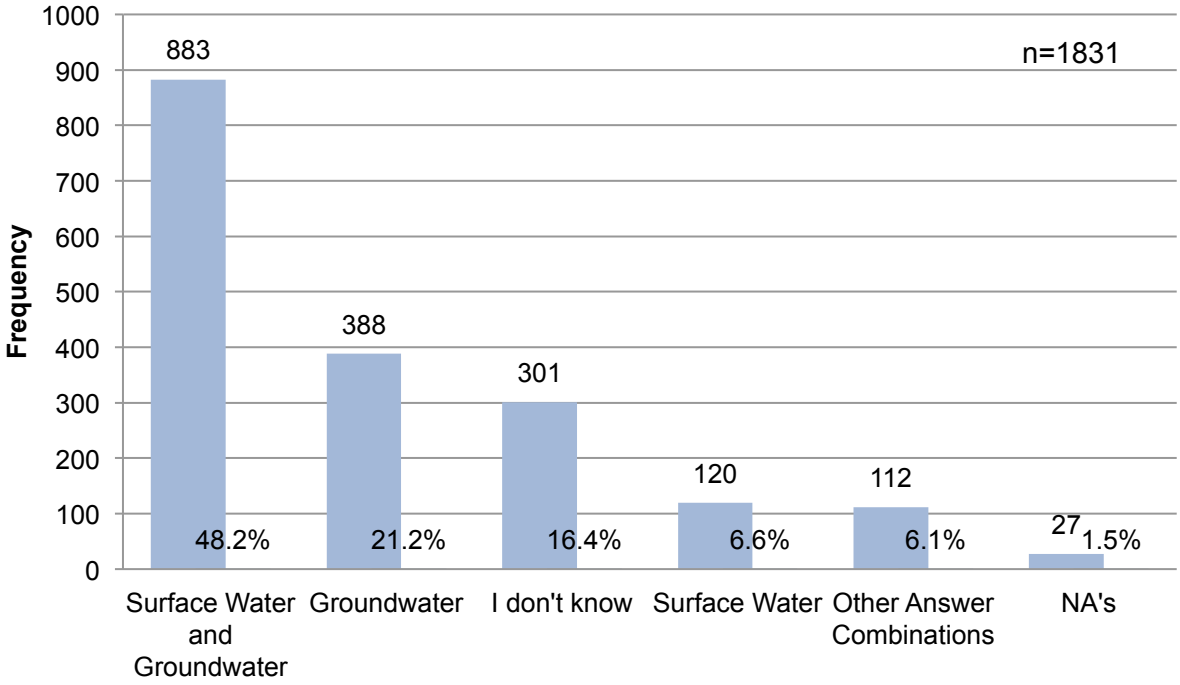


Figure 6: Most selected categories for the source of Albuquerque's water supply

These data show that nearly half of respondents know that Albuquerque's water is drawn from multiple sources. However, 21.2% of respondents selected only "Groundwater", and an additional 16.4% don't know where the water comes from at all. In fact,

Albuquerque has only recently switched to including surface water in the water supply via the San Juan Chama project in 2008, which involves the diversion of Colorado River Water via the Rio Grande. This was done in an effort to decrease the strain on Albuquerque's heavily pumped aquifer (ABCWUA, 2016).

Question 4 asked respondents: " Do you believe that the impact of climate change on the water cycle will make it more difficult for ABCWUA to meet our community's water needs in the next 10 to 40 years?" In order to compare results with those from a previous ABCWUA study, the phrasing of this question was taken directly from ABCWUA's biennial customer opinion survey, last conducted in February of 2016. The ABCWUA survey used questions from a national survey from 2013 (Water Research Foundation project #4381) to better understand how the opinions of ABCWUA customers compare to national opinions. The plot below, Figure 7, shows the comparison between these two studies.

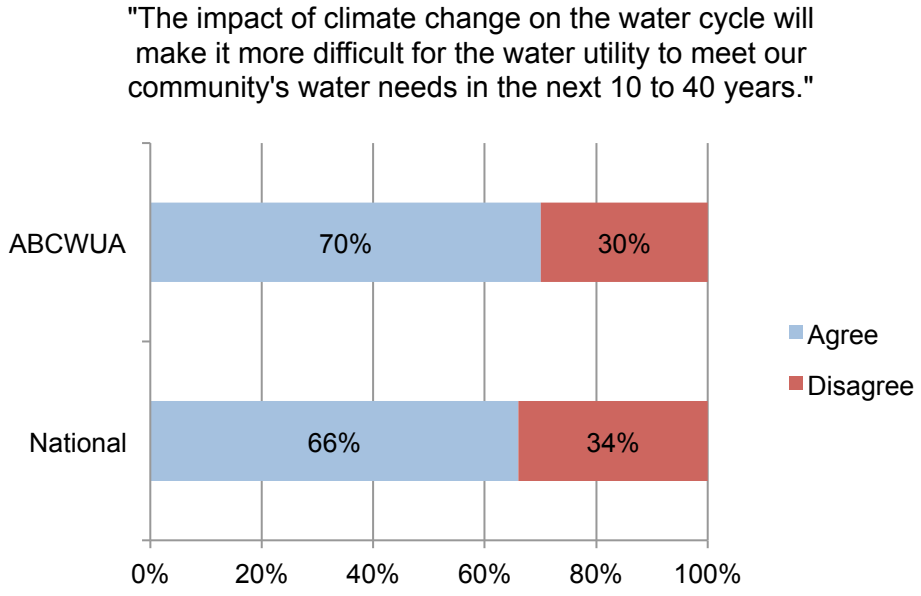


Figure 7: Comparison between climate change question responses in ABCWUA's biennial survey and a national survey by WRF

Our survey yielded similar levels of agreement, with 71% of respondents answering "Yes", 14% answering "No", and 13% answering "I don't know". The ABCWUA and WRF surveys did not include an "I don't know" response option, which captured 13% of

our survey respondents. These results are interesting and suggest that a significant proportion of the population may be undecided or need more information to form an opinion on climate change.

Questions 5 and 6 of our survey asked respondents about water usage at home and their perceived level of safety (or quality) of bottled water relative to Albuquerque tap water. These questions were partially based on a study by Millan et.al. (2015), which surveyed 1,200 California voters in 2014. In terms of types of water most often consumed at home, our data show that 28% consume city tap water, an additional 43% consume city tap water with additional filtration at home, and 18% consume bottled water most often. The breakdown of responses is shown on Figure 8.

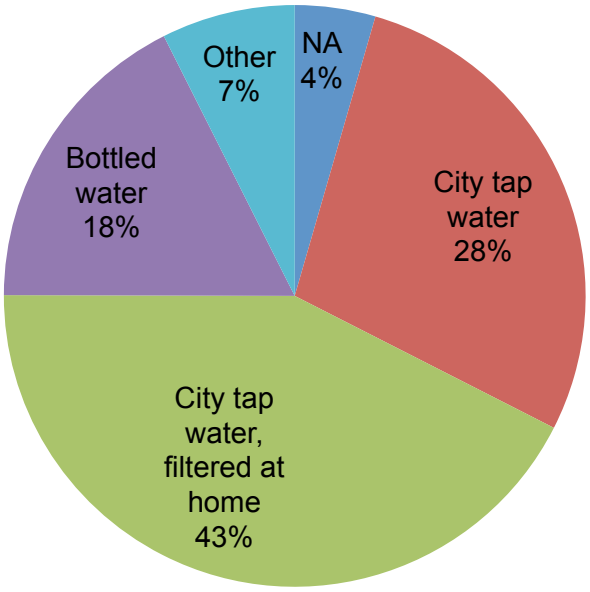


Figure 8: Water sources most often consumed at home by survey respondents, n=1831

Millan et.al.'s (2015) results show a higher percentage of bottled water drinkers (31%), a lower percentage of respondents using city tap water (21%) and a similar percentage of those who most often drink city water filtered at home (45%). Next, looking at perceptions of the safety of bottled water, our survey found that 48% of respondents do not believe that bottled water is safer than Albuquerque tap water, while 29% believe that

bottled water is safer. Cross-examining these last two survey questions, we see that bottled water drinkers may have some misperceptions about the quality of the water, as 77% of bottled water drinkers believe that it is "safer (higher quality)" than Albuquerque tap water. However, only 31% of filtered city tap water drinkers and 16% of city tap water drinkers believe that bottled water is safer.

The last question in the home water use section of our survey asks about conservation measures at home. The question allowed for multiple responses to be selected, so percentages were calculated by dividing the frequency of each response by the total number of respondents. The data show that 77.6% of respondents indicated they practice simple conservation measures such as turning off the tap when brushing teeth, 62.3% use water saving fixtures like low-flow faucets and toilets, 58.7% have a xeriscaped land/yard, and 57.3% use water efficient appliances like dishwashers and washing machines. Rainwater harvesting and not watering land are much less common among respondents. These results are summarized in Figure 9, below.

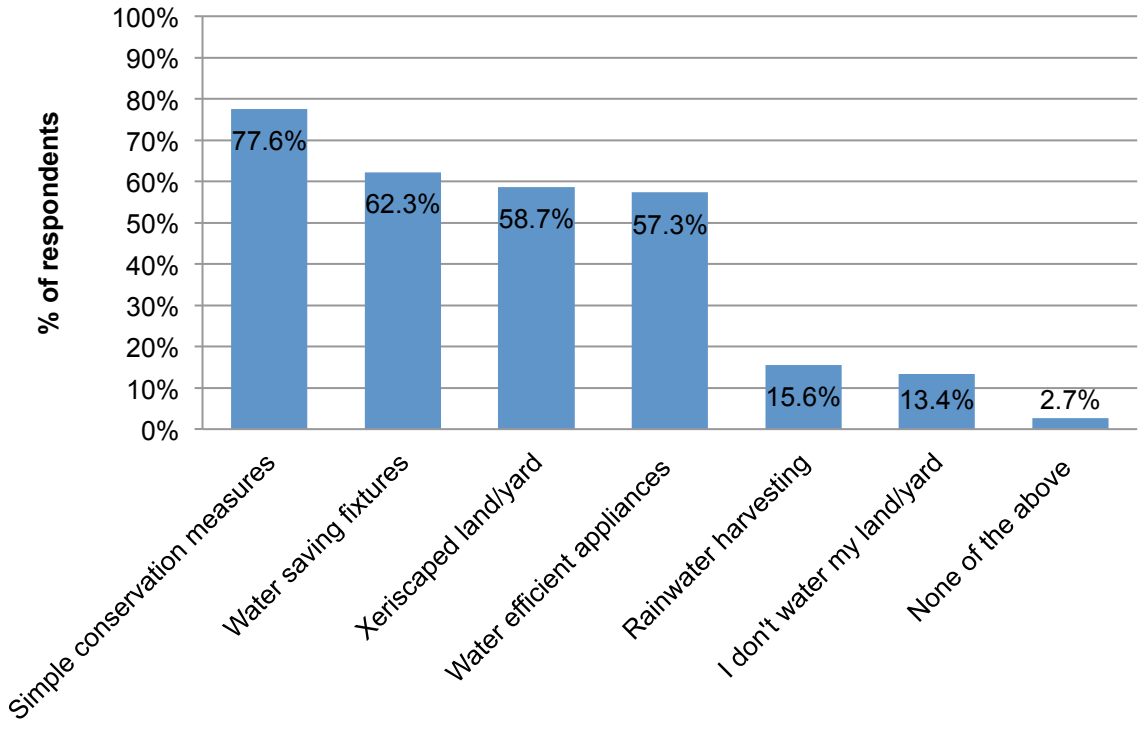


Figure 9: Conservation measures at home, by % of respondents

Looking further, 64% of respondents indicated that they practice three or more water conservation measures at home. These results suggest that the water customers who responded to the survey are generally water aware and are working to conserve the resource.

3.2.3 EDUCATIONAL MATERIALS PAGES

The next two survey questions were associated with the educational materials page of the survey and were standard across each of the four versions. The first question asked respondents on a scale of 1-5 how aware they were of water scarcity issues in New Mexico. Results show that 66% of respondents fall into either the third or fourth categories: "Moderately aware" or "Very aware." As a lead-in to the next section, the second question on the educational material pages asked the respondent if they were aware of the concept of potable water reuse. Respondents could select either "Yes" or "No" for this question. Results show that 68.5% of respondents were aware of potable reuse before the survey instrument introduced it on the following pages. While these results are worth noting and may be interesting to include as variables in future analyses, the main objective of these questions was to ensure that the respondents read the educational material page before being introduced to the potable reuse scenarios in the next section. Again, the survey versions differed by the material provided on these pages, and the impact of these materials on acceptance will be presented last, in Section 3.2.7.

3.2.4 ACCEPTANCE OF DIRECT AND INDIRECT POTABLE REUSE

This section of the survey introduced DPR and IPR, using schematics differing only by the inclusion of an environmental buffer. After being introduced to each type of reuse, respondents were asked the same three questions. The first question asked about their willingness to drink the city tap water in a community using this form of reuse. A 5-point bipolar ordinal scale was used, with the following response options: (1) "Refuse to Drink", (2) "Prefer to Avoid", (3) "Neutral", (4) "Generally OK", and (5) "Very Willing to Drink". Figure 10, below, shows the breakdown of responses for both DPR and IPR.

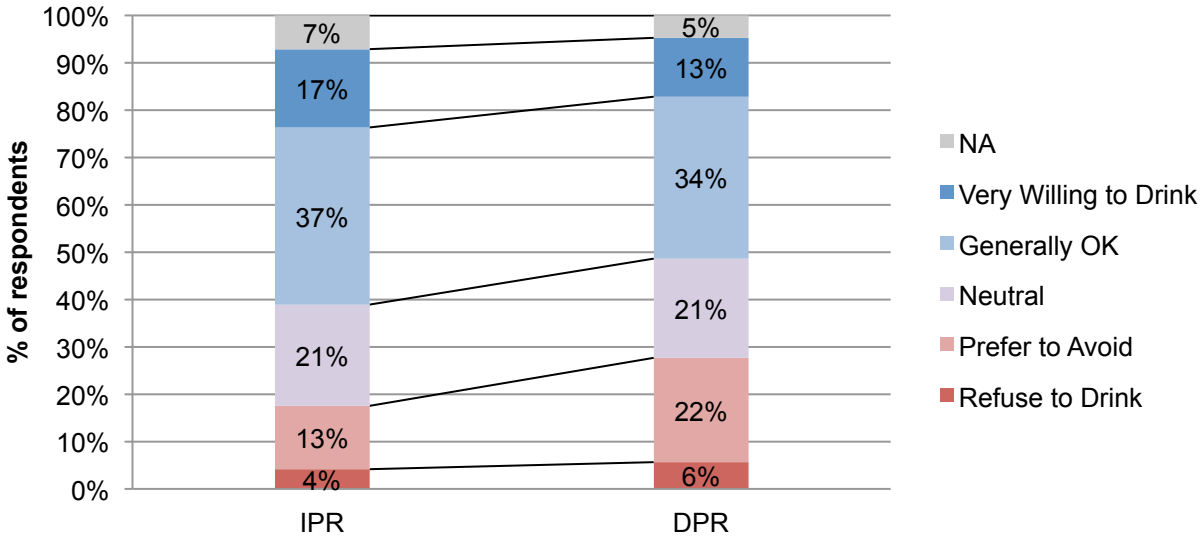


Figure 10: Breakdown of acceptance by type of reuse, 5-point scale

As expected, the data show that IPR is slightly more acceptable to respondents than DPR, with 22% stating that they would "Prefer to Avoid" DPR versus 13% for IPR. There is also a sizable "Neutral" category for both scenarios, about 21%. In order to conduct analyses on these data, the 5-point scale was collapsed to three categories, by grouping "Refuse to Drink" and "Prefer to Avoid" into an "Unwilling" category, leaving the "Neutral" category, and grouping "Generally OK" and "Very Willing to Drink" into a "Willing" category. This simplified plot is shown below, Figure 11.

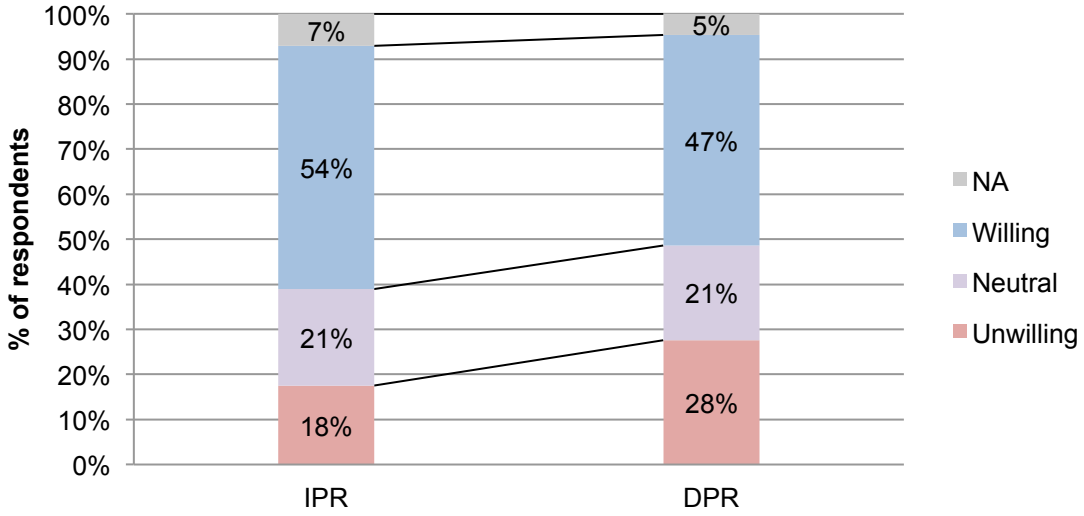


Figure 11: Breakdown of acceptance by type of reuse, collapsed to 3 categories

The "Willing" category captures the majority of respondents for both IPR and DPR, with 54% and 47% of respondents respectively. These results show that respondents are generally willing to accept IPR and DPR, but with the relatively similar size of the "Neutral" category, we see that DPR is clearly the less favored option.

The questions on willingness to drink were followed by questions pertaining to various reasons for support and concern for each type of reuse. These questions allowed for multiple options to be selected, and several of the response options were adapted from Millan et. al. (2015). Figure 12 shows the reasons for support of DPR, ranked by frequency of each selected answer.

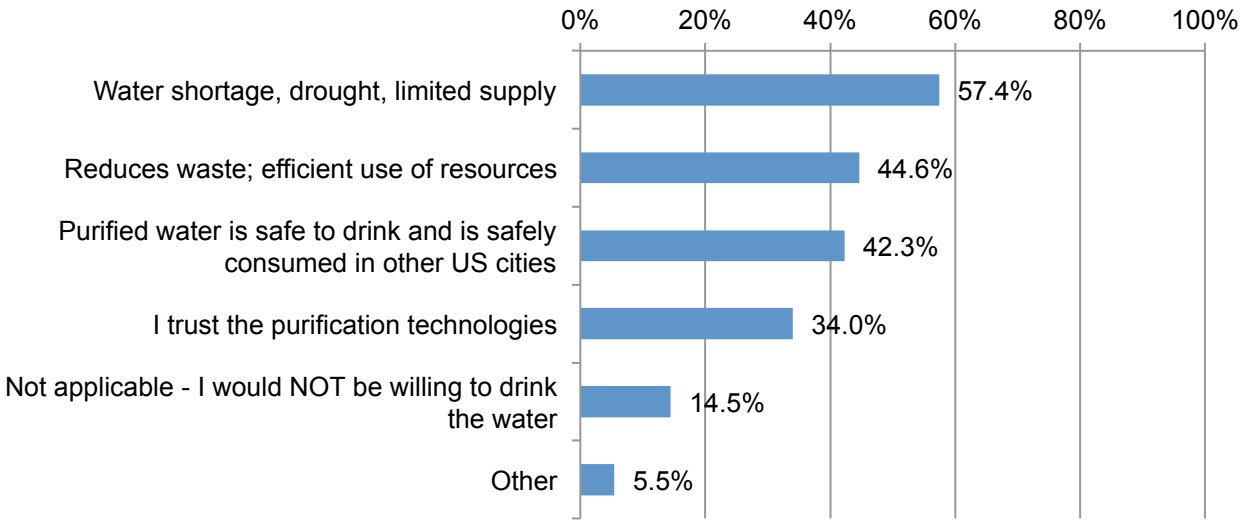


Figure 12: Reasons for DPR support, ranked by frequency

The data show that 57.4% of respondents indicated that they would be willing to support DPR in the event of water shortage, drought, or limited supply, 44.6% would be willing to support DPR because it reduces waste and uses resources efficiently, and 42.3% would be willing to support it because DPR has been safely implemented in other cities. Trust in purification technologies is one of the least supported reasons for acceptance, with only 34% of respondents selecting this answer choice. Similar results were obtained for IPR, which are summarized below in Figure 13.

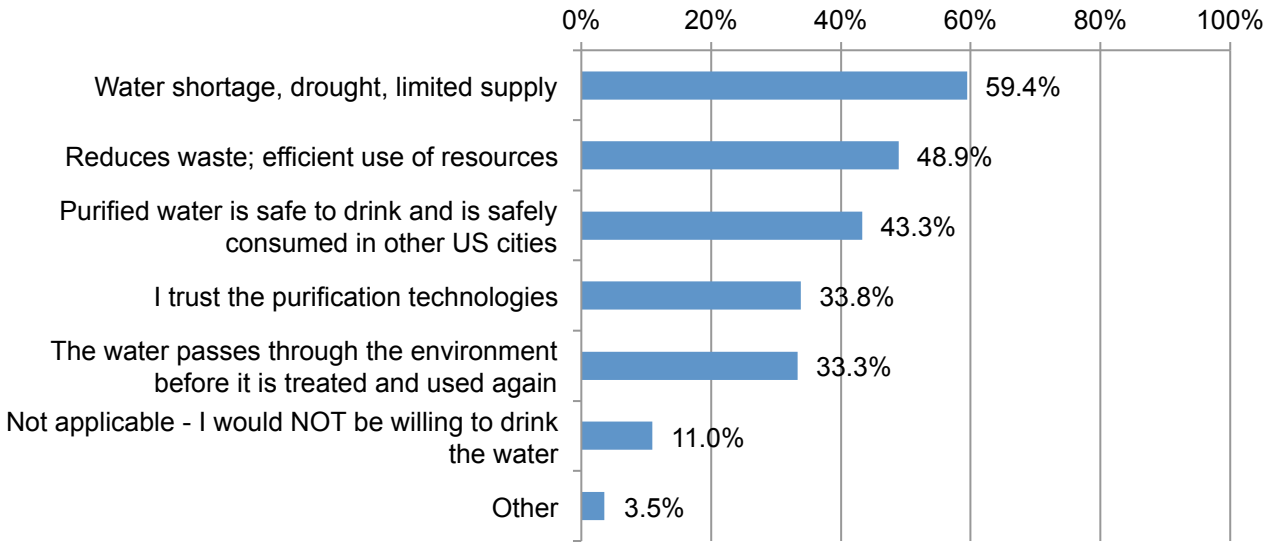


Figure 13: Reasons for IPR support, ranked by frequency

The IPR question included one additional answer option for support - that the water passes through the environment before being treated. This answer ranked relatively low compared to other reasons for support, with 33.3% of respondents. This was surprising because previous studies have suggested this as the primary reason for higher public support of IPR versus DPR. Next, the survey asked respondents about common reasons that they might be concerned with the two reuse scenarios. Figures 14 and 15 show the results for DPR and IPR respectively. Again, respondents were allowed to select multiple answer choices.

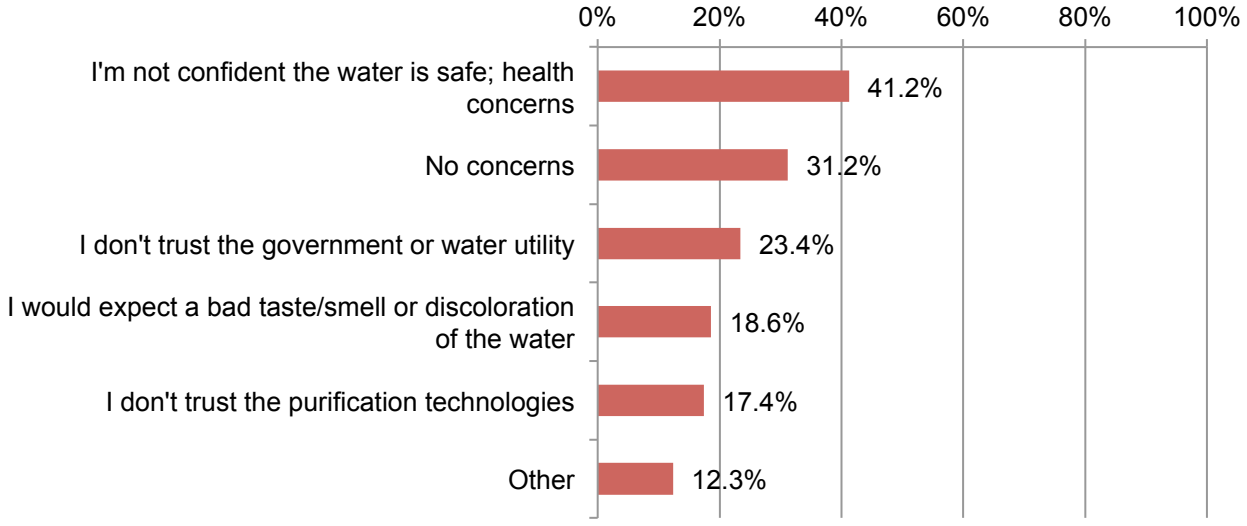


Figure 14: Reasons for concern with DPR, ranked by frequency

The main concern for DPR is that respondents are not confident that the water is safe or they have other health concerns with drinking the water. In fact, 41.2% of respondents indicated this as a concern for DPR, while only 35.7% selected this option for IPR, as shown below.

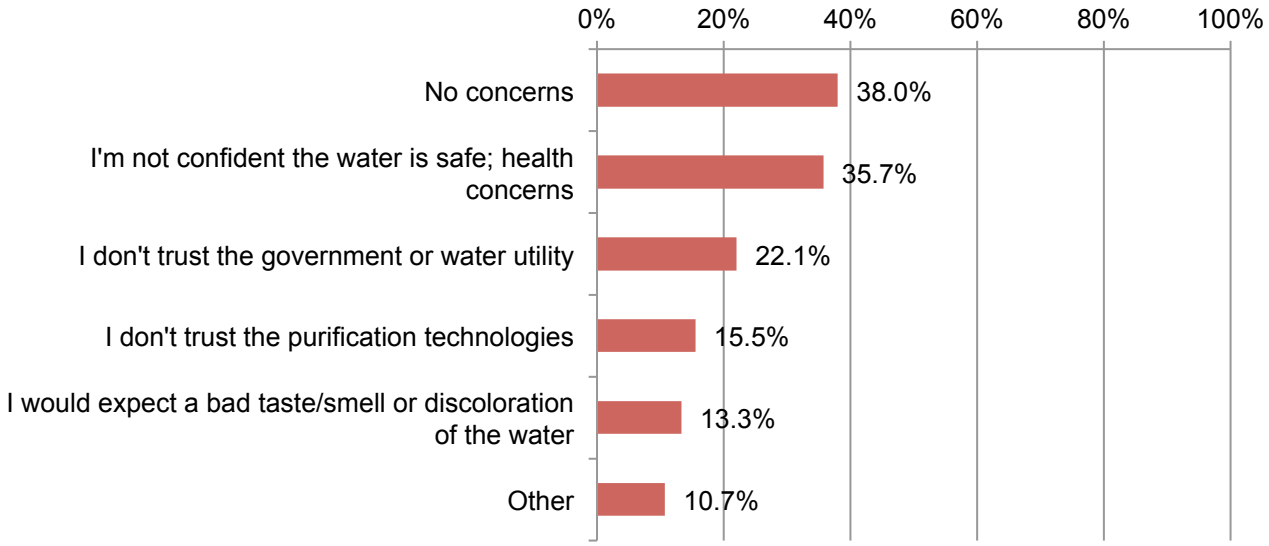


Figure 15: Reasons for concern with IPR, ranked by frequency

For both DPR and IPR, a similar proportion of respondents indicated that they do not trust the government or water utility: 23.4% and 22.1%, respectively. Respondents were slightly more concerned with a potential for bad smell or taste of the water with the DPR scenario and were slightly less trusting of the purification technologies for DPR, even though the survey indicated that the technologies for both scenarios would be identical.

The next section reiterated the key difference between the two reuse scenarios (i.e., the environmental buffer that is included in IPR, but not DPR), and asked respondents which scenario they would be more willing to accept. In addition to "IPR" and "DPR", "Both types of reuse are equally acceptable to me" and "Neither type of reuse is acceptable to me" were also listed as answer choices. Figure 16 shows a summary of these results.

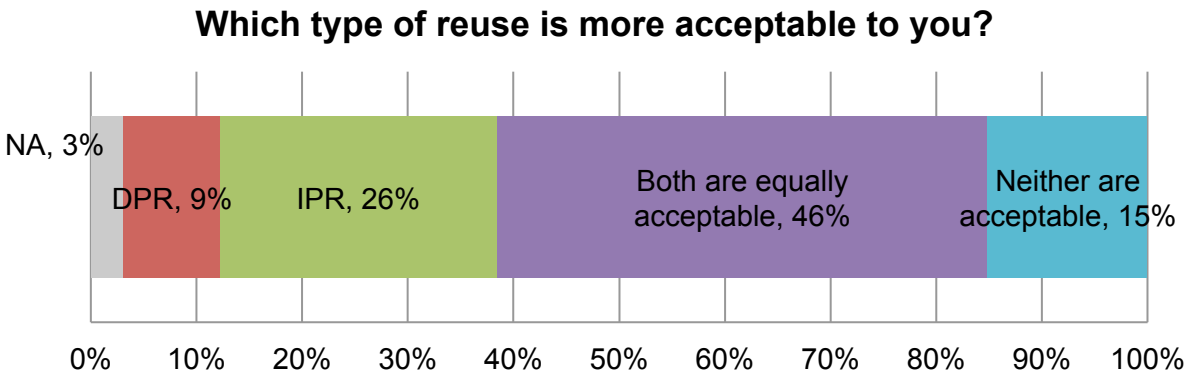


Figure 16: DPR vs IPR acceptance

Interestingly, 15% of respondents indicated that neither type of reuse is acceptable to them – when only 4 and 6% of respondents selected "Refuse to Drink" for IPR and DPR respectively in previous survey questions. Furthermore, 26% indicated that they prefer IPR as compared to the 9% who preferred DPR. These results are not surprising, as acceptance of potable reuse, especially DPR, has been a contested issue in the public eye for quite a while. However, the data also show that 46% of respondents find both types of reuse to be equally acceptable, which is higher than reported in most previous survey research on public acceptance of potable water reuse.

3.2.5 TRUST IN INSTITUTIONS

The last question of the survey, before the demographic questions, asked respondents about their level of trust in various entities to provide accurate information on water reuse. Respondents were given a list of entities and asked to rank their level of trust for each on the following scale: "Mostly Distrust", "Somewhat Distrust", "Neutral", "Somewhat Trust" or "Mostly Trust". Figure 17 shows the results of this survey question, ranked by the largest sum of "Mostly Distrust" and "Somewhat Distrust" categories.

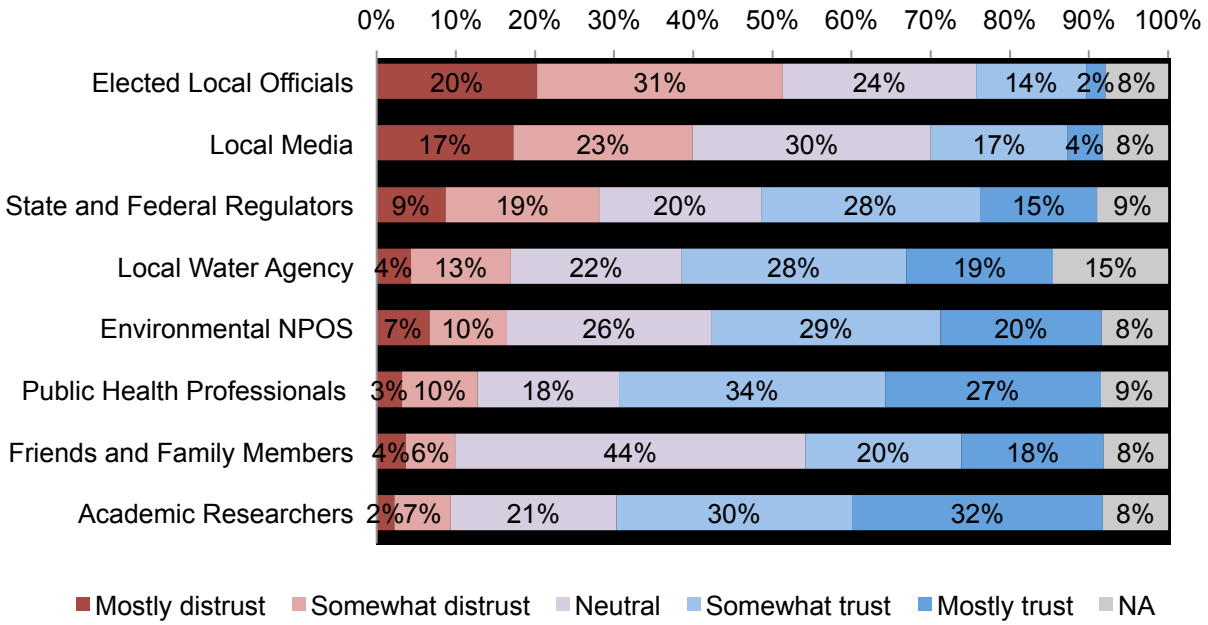


Figure 17: Level of trust in various institutions to provide accurate information on water reuse, ranked by largest "mostly distrust" and "somewhat distrust" categories

Results show that 51% of respondents distrust the elected local officials, 40% of respondents distrust the local media, and 28% distrust state and federal regulators, such as the New Mexico Environment Department or the Environmental Protection Agency. Among the most trusted entities are academic researchers and public health professionals, with 61% of respondents falling into either the "Mostly trust" or "Somewhat trust" categories. Due to the fact that academic researchers conducted this survey, the possibility for response bias on this question should be considered in assessing the result. The local water agency, ABCWUA, and environmental non-profit organizations (NPOs) are moderately trusted, with 47% and 49% falling into these categories, respectively. This information could be useful to ABCWUA in selecting the proper source(s) and/or messenger(s) to provide the public with information about potential future potable reuse scenarios.

3.2.6 DEMOGRAPHIC DATA

The survey collected data on nine different topics: age, gender, children at home, whether an individual is native to New Mexico, ethnicity, race, education level, political affiliation, and annual household income. These results are summarized in Table 6.

Table 6: Demographic characteristics of the sample, frequency (n) and percent

	n*	Percent	NAs	% Total Respondents
Age				
18-24	26	1.5%	72	3.9%
25-44	396	22.5%		
45-64	733	41.7%		
65+	604	34.3%		
Gender				
Female	944	53.1%	52	2.8%
Male	832	46.8%		
Other	3	0.2%		
Children at Home (<18 y/o)				
Yes	469	26.4%	52	2.8%
No	1310	73.6%		
New Mexico Native (Long-term NM resident)				
Yes	1275	71.4%	46	2.5%
No	510	28.6%		
Ethnicity (Spanish/Hispanic/Latino)				
Yes	595	34.1%	87	4.8%
No	1149	65.9%		
Race (ranked by frequency)				
White	1391	80.4%	101	5.5%
Other	188	10.9%		
Mixed Race	58	3.4%		
Black	33	1.9%		
American Indian	31	1.8%		
Asian	25	1.4%		
Pacific Islander	4	0.2%		
Education Level				
High school degree or less	246	13.9%	57	3.1%
Some college	583	32.9%		
College degree	436	24.6%		
Advanced degree	509	28.7%		
Political Affiliation (ranked by frequency)				
Democrat	802	46.4%	104	5.7%
Republican	395	22.9%		
Independent	238	13.8%		
No Affiliation	238	13.8%		
Libertarian	40	2.3%		
Green	14	0.8%		

Annual Household Income					
1	Less than $14,999	81	4.9%		
2	$15,000 - $24,999	133	8.1%		
3	$25,000 - $34,999	143	8.7%		
4	$35,000 - $49,999	221	13.4%		
5	$50,000 - $74,999	371	22.5%	179	9.8%
6	$75,000 - $99,999	251	15.2%		
7	$100,000 - $149,999	256	15.5%		
8	$150,000 - $199,999	97	5.9%		
9	$200,000 or more	99	6.0%		

* n will not be equal to 1831 for each variable due to missing data (NAs)

Table 6 shows the frequency of each selected answer for each demographic variable, as well as the percent breakdown (excluding missing data.) The number of missing responses and the percent of total respondents (n=1831) for each variable are reported in the columns on the right side of Table 6. In summary, 76% of the survey sample is 45 years or older. The median age of the sample was 58 years, and the mean was 56.6 years. About 71% of the survey sample is native to New Mexico (lived in New Mexico for most of their life). About 34% of the sample is of Spanish/Hispanic/Latino ethnicity, and over 80% of the sample identified as "White." The survey question on race allowed for multiple answer options to be selected. The category "Mixed Race" was created for those who selected more than one race, accounting for about 3% of survey respondents. The majority of the survey sample (46%) identified their political affiliation as "Democrat", 23% identified as "Republican", 14% as "Independent", and 14% as "No Affiliation." These last two categories were later combined for analyses. Additionally, the "Libertarian" and "Green" categories were combined into an "Other" category.

As previously discussed, due to geographic and possible demographic differences between the sample population (ABCWUA customers) and the population of Bernalillo county, caution should be taken in conducting comparison analyses using US Census or American Community Survey data to determine representativeness. That is, statements made about characteristics of the survey sample may not be generalizable to the populations of Albuquerque or Bernalillo County. It may be useful for future analyses to create a comparison table that provides demographic data from Bernalillo County,

Bernalillo County property owners, and the data from this survey side by side. As a preliminary analysis, the income level and education level data collected for the survey sample can be plotted with data for Bernalillo County to see where the sample stands in comparison. Figure 18 shows the proportion of survey respondents and Bernalillo County residents falling into the categories for education level, as defined in Table 6.

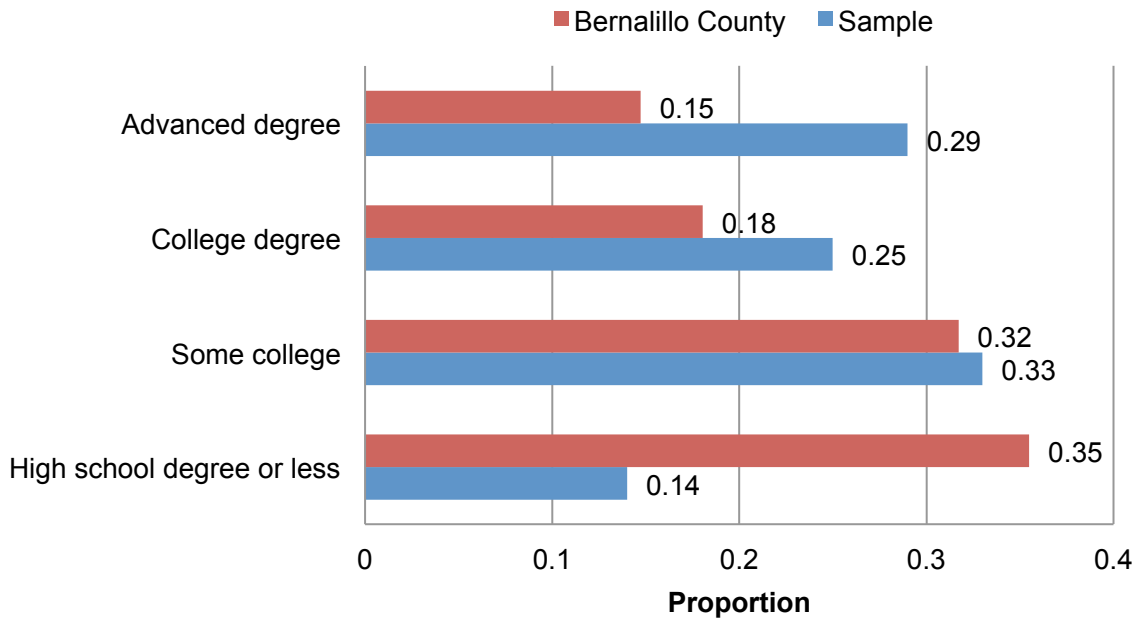


Figure 18: Education level of survey sample data compared with Bernalillo County data (2012-2016 American Community Survey (ACS) 5-Year Estimates)

Generally, the proportion of survey respondents falling into the "Low" education level is much lower than the proportion for Bernalillo County. This is reflected by higher proportions in the "Mid" and "High" categories, suggesting that the survey sample is generally more educated than the county as a whole. A similar comparison was made for income level, as shown in Figure 19. For reference, Table 6 defines the categories for income level.

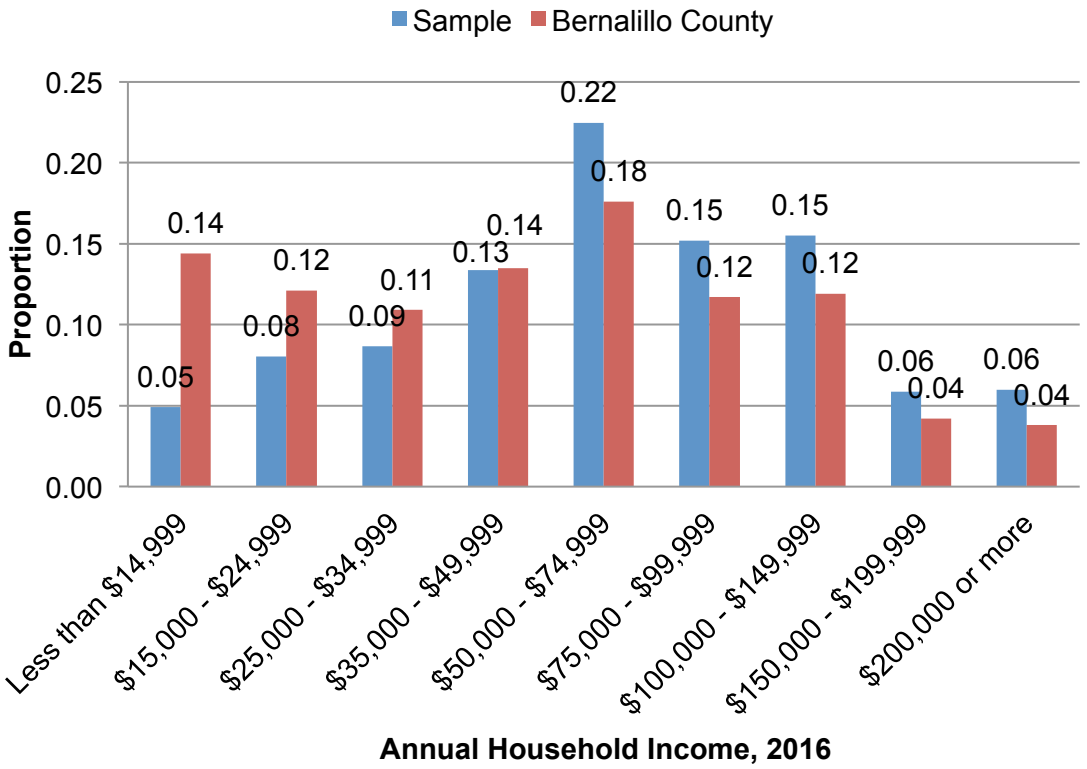


Figure 19: Annual income level of survey sample data compared with Bernalillo County data (2012-2016 ACS 5-Year Estimates)

Overall, the proportions falling into each income category for the survey sample match the general trend for Bernalillo County. Not surprisingly, the largest discrepancy is on the low end of the income categories, with the survey sample containing a lower proportion of lower income respondents compared to the county data. This could explain some of the expected differences in income between the sample population, which contains mostly homeowners, and Bernalillo County as a whole, which also includes renters. While the proportion of lower income categories is lower for the sample, this is made up in the fifth category, with a higher proportion of respondents earning between $50,000 and $74,999 annually than is reported for Bernalillo County residents. It should be noted that 9.8% of respondents chose not to answer this question, so response bias may have also played a role. That is, those who are in the lower or higher-end income categories may have been less likely to respond. In summary, the survey data sample appears to be predominantly white, middle class, and relatively highly educated.

3.2.7 FACTORS IMPACTING ACCEPTANCE OF POTABLE REUSE

Among other research questions, this survey aimed to investigate the impact of educational materials on a respondent's willingness to accept two different potable reuse scenarios. Each respondent received one of four versions of the survey, which differed based on the version of educational materials, or lack thereof, included in the survey. Analyses were done in R to predict a respondent's willingness to accept the scenarios, based on the version of the survey they received. First, the proportion of respondents in the "Willing" category for each scenario was plotted for each of the four versions of the survey. While the differences between willingness to accept DPR and IPR are apparent, the differences between survey versions are not. To reiterate, Version 1 of the survey served as the control group, and respondents who received this version did not receive an educational materials page. Version 2 focused on water scarcity, Version 3 on the environmental benefits of reuse, and Version 4 on the urban water cycle. Figure 20 below shows the proportion of respondents that fell into each category.

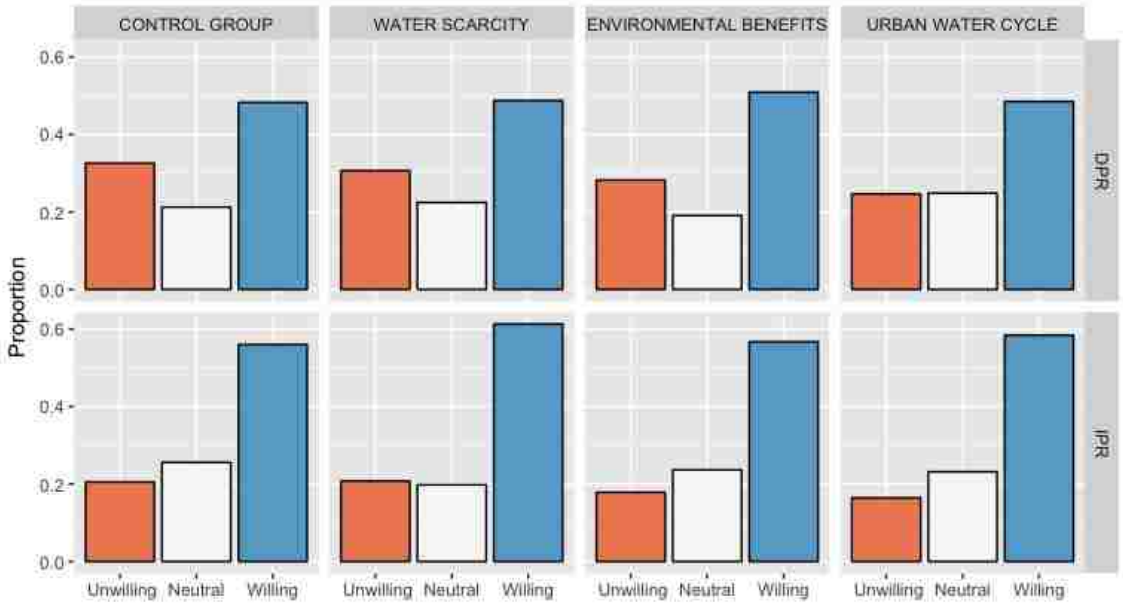


Figure 20: Willingness to accept two reuse scenarios, by survey version

Between survey versions, there are slight differences in willingness to accept, yet these differences were not statistically significant.

Also known as a proportional log odds model or cumulative link model, ordered logistic regression attempts to predict which (ordered) category a respondent will fall into, based on one or more predictor variables. Using a single binary predictor variable based on the survey version (`VERSION_BIN`), the cumulative link model function in R was used to estimate the probability that an individual would fall into each category of willingness ("Unwilling, "Neutral", and "Willing") for both IPR and DPR. In this model, the three versions of the survey with educational materials were grouped together in order to evaluate against the control group. Initially, the model was run with the educational materials ungrouped, but the results showed no significant difference between survey versions. While neither model produced statistically significant results, grouping the materials together gives more predictive power and slightly lower standard error. Additionally, the proportional log odds assumption was better met for the model with combined educational materials. Table 7 shows the predicted probabilities with standard errors, as well as the coefficient output of the models for both IPR and DPR.

Table 7: Predicted probabilities of willingness levels, including standard error and model coefficients, n= 1701 (IPR), 1746 (DPR)

	Coefficients		
	θ1	θ2	β
IPR	-1.337	-0.203	-0.166
DPR	-0.808	0.128	-0.119

	With Educational Materials (X = 1)			**Standard Error**		
	Unwilling, π1	Neutral, π2	Willing, π3	π1	π2	π3
IPR	0.182	0.227	0.591	0.010	0.010	0.014
DPR	0.284	0.219	0.498	0.012	0.010	0.014

	Control Group (X = 0)			**Standard Error**		
	Unwilling, π1	Neutral, π2	Willing, π3	π1	π2	π3
IPR	0.208	0.241	0.551	0.016	0.012	0.023
DPR	0.308	0.224	0.468	0.020	0.010	0.023

The following table is provided to summarize the above results in terms of predicted probability falling into the "Willing" category, based on the presence of educational materials.

Table 8: Predicted probabilities of willingness for IPR and DPR, based on whether educational materials were provided

	With Educational Materials	Control Group	Difference	p- value
IPR	0.591	0.551	3.5%	0.121
DPR	0.498	0.468	2.9%	0.252

While these results were not found to be statistically significant (p=0.121 for IPR, p=0.252 for DPR), in both cases the educational materials had a non-trivial positive effect, indicating that future work should examine the effect of educational materials more closely. When these probabilities are plotted with 95% confidence bands, Figure 21, the differences between the control group and the educational materials group can be visualized.

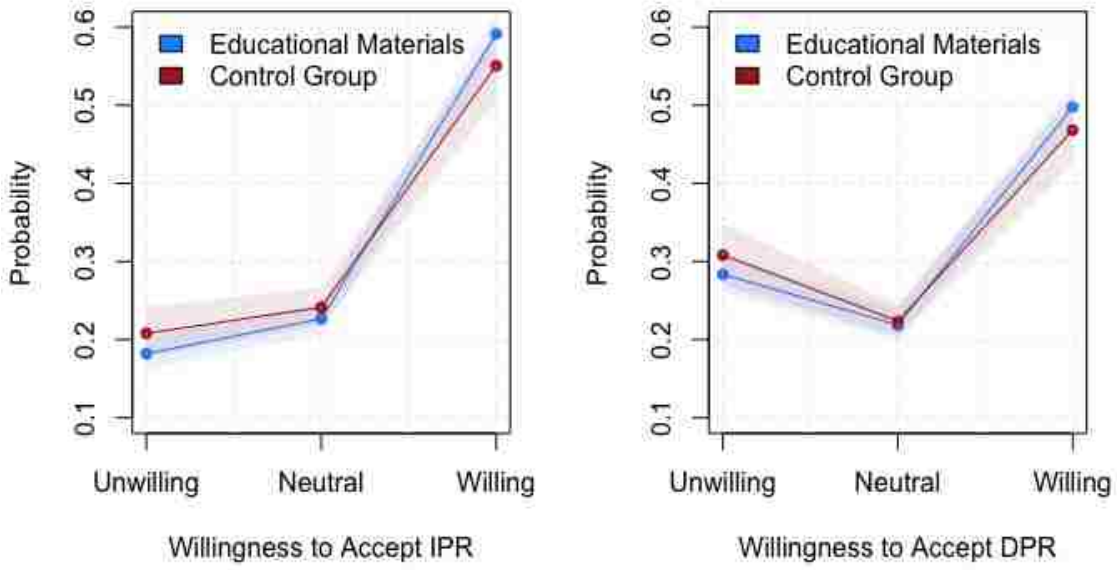


Figure 21: Plots comparing predicted probabilities of willingness to accept levels, IPR and DPR

Though the confidence bands overlap, these plots illustrate the slight differences in probabilities between the control group and the educational materials group.

Next, using the demographic data as well as water related variables such as prior knowledge of potable reuse collected by the survey; an ordered logistic regression model

was fit in order to examine the predictive power of these variables on acceptance of both reuse scenarios. One assumption that underlies ordered logistic regression models is the proportional log-odds assumption, which assumes that the effects of explanatory variables are consistent across the pairs of categories in the ordered logistic regression (Unwilling|Neutral, Neutral|Willing). This assumption is also referred to as the test of parallel lines, which is done separately for each variable in the model. A rough test of this assumption was done in R for each of the variables included in the model, and it was determined that the proportional log-odds assumption was met. Based on the results of these models, it was determined that several variables were significant at varying levels of significance. The output of these models for DPR and IPR, including the model coefficients and associated p-values, are listed below in Table 9.

Table 9: Summary of model coefficients predicting DPR and IPR willingness

DPR	Estimate	Std. Error	Significance Codes[2]
MALE	0.2791	0.1003	**
COLLEGE DEGREE	-0.1184	0.1377	
HIGH SCHOOL DEGREE OR LESS	-0.4956	0.1689	**
SOME COLLEGE	-0.5455	0.1301	***
NEW MEXICO NATIVE	0.2448	0.1098	*
AWARE OF REUSE	0.4541	0.1088	***
IPR			
MALE	0.2907	0.1079	**
INDEPENDENT/NO AFFILIATION[3]	-0.3528	0.1269	**
OTHER AFFILIATION	-0.0088	0.3119	
REPUBLICAN	0.0471	0.1382	
COLLEGE DEGREE	-0.0297	0.1502	
HIGH SCHOOL DEGREE OR LESS	-0.6653	0.1771	***
SOME COLLEGE	-0.5344	0.1392	***
NEW MEXICO NATIVE	0.2645	0.1173	*
AWARE OF REUSE	0.5337	0.1148	***

[2] Significance level codes for p-values: 0.001 = "***", 0.01 = "**", 0.05 = "*", 0.10 = "."
[3] Variables with more than two categories retained by the model should be interpreted in comparison to the omitted group. For the political affiliation variable, the omitted group was "Democrat", meaning that the magnitude and direction of coefficients for the other political groups should be interpreted in comparison to "Democrat". The omitted group for education level was "Advanced Degree".

The variables retained by the model selection process were similar for DPR and IPR, differing only by level of significance - with the exception that model for IPR retained the political affiliation variable. The impact of the variable on willingness to accept is determined by the sign of the value in the "Estimate" column for each variable. That is, if the "Estimate" coefficient is negative, that variable will have a negative impact on the probability of willingness.

For both DPR and IPR, if a respondent has prior knowledge of reuse, is male, or is native to New Mexico (has lived in New Mexico for most of their life), they are more likely to fall into the "Willing" category. Compared to those with advanced degrees, those falling into the other lesser education categories are less likely to accept reuse. For IPR, the model shows that those who identify as "Independent or No Affiliation" are less likely to accept than those identifying as "Democrat". The significance levels for these variables, as well as the magnitude and direction of their predictive power are reported in the table above.

These results suggest that prior knowledge of reuse plays a large role in acceptance – that those who are already educated on the topic are more willing to accept the practice. Results also show that respondents who are male and native to New Mexico may not need to be as much of a focus in targeted communication and outreach campaigns. Interestingly, for IPR, the models show that political affiliation may play a role in acceptance of reuse.

3.3 STUDY LIMITATIONS

One limitation of this study that first appeared during the survey refinement process was underrepresentation from the southwest quadrant of the city. Unlike the other focus groups, ten participants were not recruited for either of the focus groups held in that quadrant. In fact, one of these focus groups was cancelled due to lack of participant interest, and the other had only one participant, who was scheduled for a debriefing session instead. Despite heavy advertising on and around the University of New Mexico campus and on social media and online platforms, those self-selecting to participate in the focus groups were generally older, educated, white residents who had an existing interest

in New Mexico water issues. This limitation reappeared in the survey response data. While southwest quadrant residents made up 16.3% of ABCWUA's customer list, they make up only 12.3% of our survey respondents. On the other hand, we saw a higher-than-proportional degree of participation from the northeast quadrant of the city as compared to what we would expect based on representation in the customer list. The proportions for the other two quadrants, northwest and southeast, were within 1% of the ABCWUA list. This issue can be looked into further by examining survey response rates by Census tract. Mapping software was used to determine the response rate for the survey for each census tract in Bernalillo County and the ABCWUA service area. The response rates in Figure 22 below were calculated by dividing the number of completed surveys received by the total number of surveys sent to each tract. This calculation does not take into account respondents of unknown eligibility (e.g.: surveys sent to vacant homes or incorrect addresses).

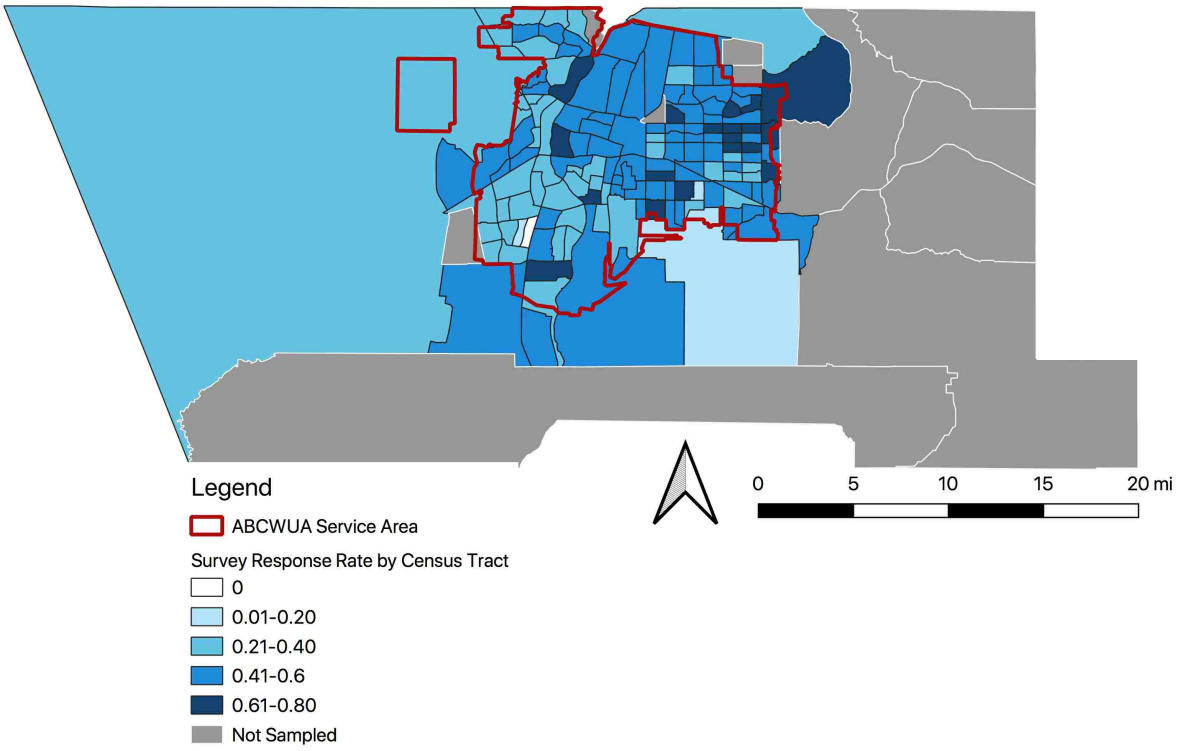


Figure 22: Map of Bernalillo County and ABCWUA service area, showing survey response rate by Census tract

The map shows a clustering of tracts with higher than average response rates in the NE quadrant of the city, and lower response rates in the SE and SW. Visualizing the data in

this way can help to determine trends and pinpoint areas with low response rates that may need additional attention in future studies.

Another limitation of this study was that no aspect of the survey was conducted in Spanish (i.e., focus groups were not held in Spanish and the option to take a Spanish-translation survey was not given). Albuquerque and Bernalillo County have significant Spanish speaking populations, so it is important to note that the survey instrument may not have been accessible to a portion of the sample. Though approximately 25% of Bernalillo County residents speak Spanish at home according to the 2012-2016 American Community Survey (ACS) 5-year estimates, the costs associated with conducting the survey design, refinement, and administration processes in a second language were prohibitive.

Recognizing these limitations, we must use caution in comparing the demographic data collected by our survey with Bernalillo County data. Furthermore, given that ABCWUA does not collect demographic data on its customers, there is not sufficient data to use in calculations to determine the representativeness of our sample.

CHAPTER 4: CONCLUSIONS

Beyond testing the impact of educational materials on acceptance of reuse scenarios, this survey collected attitudinal data on water scarcity, climate change, water habits at home, and trust in institutions, among other topics. Collecting this data on a large scale was beneficial in understanding where the public stands on somewhat contentious topics surrounding the environment, especially given the arid inland context – a context that has not been adequately explored regarding these topics in the literature to date.

4.1 SUMMARY OF KEY FINDINGS

In terms of concern with community issues, ABCWUA customers are most concerned with the crime rate and the quality of public education. The water issues like drought and the quality of drinking water ranked 4th and 5th on the list of eight issues facing the county. These rankings reflect current major challenges facing the state and should not be seen as a suggestion that public outreach and education are not needed regarding potable water reuse.

Other interesting findings related to residents' knowledge of water issues were that nearly half of the ABCWUA customers surveyed know that the drinking water supply in Albuquerque comes from both surface and groundwater sources, while about 17% did not know at all from where their drinking water is sourced. Seventy-one percent of customers surveyed believe that climate change will impact the ability of the ABCWUA to provide reliable water supplies in the future.

In terms of type of water most frequently used at home, the majority of survey respondents filter the city tap water at home (43%), 28% drink the city tap water directly, and only 18% drink bottled water. It seems that bottled water drinkers have some misperceptions about the quality, as 77% believe that it is "safer (higher quality)" than Albuquerque tap water, compared to 31% and 16% of filtered city tap water drinkers and city tap water drinkers, respectively. Sixty-four percent of ABCWUA customers surveyed stated that they practice three or more water conservation measures at home.

Concerning the two water reuse scenarios presented by the survey, 54% were willing to drink the water from a community with IPR, compared to 47% for a community with DPR. The neutral category captured about 21% of the response for both scenarios. Overall, DPR is less acceptable, with 28% of respondents indicating they would not be willing or would prefer not to drink the water.

The most common reason for accepting both types of reuse was water shortage and drought, with 57% and 59% of respondents selecting this answer option for DPR and IPR, respectively. The second most common response for both types of reuse was that reuse could reduce waste and is an efficient use of resources, with 45% and 49% respectively.

Discussing areas of concern with the reuse scenarios, 41% of respondents were not confident that the water was safe, or had health concerns with DPR, compared to 36% with IPR. About 22% of respondents would be concerned with both reuse scenarios due to lack of trust in the government or water utility.

Among the least trusted entities are elected local officials and the local media. The most trusted entities were academic researchers and public health officials, with 61% of respondents indicating that they "Somewhat trust" or "Mostly trust" these entities. The water utility was moderately trusted, with 47% falling into these top two categories.

The demographic data collected from the sample indicates that the majority of respondents were white, middle class, and relatively highly educated. Direct comparisons could not be made to test for representativeness, as demographic data on the ABCWUA customer base as a whole was not available.

Ordered logistic regression results show that the educational materials provided had little to no impact on the level of acceptance of either scenario, though a non-trivial positive effect was observed. In fact, the positive impact of educational materials on willingness to accept IPR was marginally significant ($p= 0.121$). However in additional analyses,

several predictors of willingness to accept were identified. If a respondent is male, native to New Mexico, or has prior knowledge of reuse, they are more likely to accept both types of reuse. Those in the "High school or less" or "Some College" education levels (compared to those with advanced degrees) were less likely to accept both types of reuse; and those without political affiliation (compared to Democrats) were less likely to accept IPR. The results of this survey may be useful to water utilities and regulators considering public communication and education related to reuse projects, the feasibility of reuse in their communities, and/or conducting their own public acceptance surveys.

4.2 POLICY IMPLICATIONS

The data collected on water habits, opinions on water scarcity and climate change, and level of trust in various entities serve as good starting place in understanding the perceptions and attitudes of water customers in the area. The following recommendations or policy implications may be useful to regulators and water planners who are part of the planning and implementation processes for potable reuse projects.

Targeted outreach to underrepresented groups. This study has identified several groups that may be receiving limited information on water scarcity and climate change related topics – including information on water reuse. Specifically, those who are younger and of lower economic status are more likely to be renters and may not be reached through public education strategies in this study or those conducted by the ABCWUA. Furthermore, this study did not specifically reach out to the Spanish speaking population of Albuquerque. Water planners considering potable reuse should work to ensure that information surrounding potential water reuse projects, as well as information on water scarcity issues reach as much of the population as possible.

Targeted communication and dialogue with groups who are more likely to be unwilling to accept reuse. This study found that several demographic variables may help predict the likelihood of a person being willing (or unwilling) to accept reuse. Specifically, women, those with no political affiliation (compared to Democrats), and those in the "High school or less" and "Some College" education categories (compared to those with advanced degrees) are less likely to be willing to accept reuse. This study also suggests

that those who oppose reuse are most concerned with the potential negative health impacts, or are not confident the water is safe. Communication and opening a dialogue about these topics may be the first step in reducing resistance to potable reuse.

If a community is considering potable reuse, public education and outreach should begin early. The ABCWUA has identified both IPR and DPR as parts of their 100-year water plan for the region. As utilities in arid regions begin to consider reuse, public outreach and communication will be essential to the successful implementation of these projects. In order to ensure that as many people as possible are informed, these efforts must begin early and continue throughout the course of the project. Approximately half of the respondents to our survey didn't know exactly which sources the drinking water in Albuquerque comes from, suggesting that a decent portion of the population of interest may have limited water knowledge in general. Our study also found that if a person has prior knowledge of potable reuse, they may be more likely to accept it. This being said, educating children and young adults about topics related to water scarcity, reuse, and the water cycle at a basic level is essential to fostering continued interest and knowledge of these topics.

4.3 FUTURE RESEARCH

Future research should include the expansion of the cumulative link models that predict acceptance of IPR and DPR to include interaction terms between predictor variables, as well as additional predictor variables of interest. The model should incorporate variables describing levels of trust in various entities. Our results show that the public trusts academic researchers and public health professionals the most, but the impact of this trust on acceptance has yet to be investigated. Similarly, trust in elected local officials and local media was determined to be low, yet the impact that this lack of trust has on acceptance of reuse is not known.

Another interesting question not yet addressed deals with the reasons for concern with IPR and DPR. Results show that 41% of respondents were not confident that the water was safe, or had health concerns with DPR, compared to 35.7% for IPR. What factors, or

perhaps demographic characteristics, might explain this large proportion of respondents indicating that they have health concerns?

Initial analyses show that the one-page educational materials provided in the survey did not significantly impact predicted levels of acceptance. Future work might include more in-depth educational materials, or a different method or study design altogether to provide the sample with educational materials.

Finally, one interesting topic that was originally to be addressed by this study is the impact of costs on acceptance of reuse scenarios. Future work may investigate a customer's willingness to pay for various scenarios or determine the level of acceptance based on a standardized cost to the customer.

Following submission of this thesis and publication of the associated articles, it is intended that the data set be made publicly available, in the hope that it will aide in further research on water scarcity and climate change related topics in arid inland areas.

CHAPTER 5: APPENDICES

APPENDIX A. Survey Contact Materials

Albuquerque Bernalillo County
Water Utility Authority

PO Box 568
Albuquerque, NM 87103
www.abcwua.org

Dear ABCWUA Customer,

As the Water Authority works to ensure that our water supply remains sustainable and resilient, we look to the public for input. I am writing to request your help in improving the Water Authority's understanding of customers' views on water reuse and other important water-related issues.

You will soon be receiving a survey in the mail from the University of New Mexico Water Resources and Community & Regional Planning Programs. This survey is going to a randomly selected sample of our residential water customers to gather opinions on water reuse and related issues. Your input will both contribute to research and inform the Water Authority about the level of public support for various potential future water projects.

Because you are among the small number of randomly selected water utility customers we have selected to take the survey, **your response is very important**. The survey will only be useful if everyone who gets the survey completes it. As a token of appreciation for your effort, the first 500 customers to return the survey will be entered in a raffle to win a rain barrel.

If you have any questions, please contact the UNM survey team at abqwatersurvey@gmail.com or (505) 277-2283.

Thank you very much for helping us better understand public opinions about water issues in the community and for contributing to this valuable research.

Sincerely,

Katherine M. Yuhas

Katherine M. Yuhas
Water Resources Division Manager

UNM SCHOOL of ARCHITECTURE & PLANNING

[DATE]

Dear Water Utility customer,

I'm Lauren Distler, a graduate student researcher at the University of New Mexico. On behalf of my research team, I'm writing to ask for your help with a survey of Water Utility customers being conducted to fulfill the requirements for my Masters degree in Water Resources and Community & Regional Planning. The survey will give you the chance to provide your opinions on water reuse scenarios that could potentially be implemented in Albuquerque, and the information we collect will help the Water Utility make informed decisions about our future water supply.

You've been randomly selected as part of a sample of residential water utility customers to take the survey. Survey results will only be useful if a high percentage of customers in the sample actually complete the entire survey. As a member of this sample, you are representing many other utility customers, so it is very important that we hear back from you. As a small thank you, we have enclosed $2. We have also included a stamped return envelope for your convenience. ***If you would prefer to complete the survey online, you may do so using the web address and code at the bottom of this letter.***

Please note that your survey answers will be kept completely confidential. When you return your survey or complete the online version, your address will be removed from our mailing list, and your answers will not be connected to you in any way.

By taking a few minutes, you will be enhancing our understanding of Water Utility customers' views on water reuse and other important issues. We thank you for your time – your opinion truly matters! If you have any questions, contact the UNM survey team at abqwatersurvey@gmail.com or (505) 277-2283.

Sincerely,

Lauren Distler
MWR & MCRP Dual Degree Candidate
University of New Mexico

Dr. Caroline Scruggs
Assistant Professor
University of New Mexico

P.S. If you are one of the first 500 customers to return the survey, you will be entered into a raffle to win a rain barrel.

WEB LINK: www.surveymonkey.com/r/water[XX]
SIX DIGIT CODE: [XXXXXX]

FRONT

UNM SCHOOL of ARCHITECTURE & PLANNING

Water Utility Customer
[ADDRESS]
Albuquerque, NM
[ZIP]

WEB LINK: www.surveymonkey.com/r/water[XX]
SIX DIGIT CODE: [XXXXXX]

BACK

Last week we mailed you a survey that asked your opinions on water reuse and other water-related topics. The information we are collecting will help UNM researchers and the Albuquerque Bernalillo County Water Utility Authority understand public support for potential water reuse projects in our community.

Your response is very important. If you have already completed and returned the survey, we'd like to thank you for your response. Your input is essential to gaining a better understanding of Water Utility customers' perspectives on water issues.

If you haven't received a survey or if it was misplaced, please contact the UNM survey team at abqwatersurvey@gmail.com or (505) 277-2283 and we will mail you another one immediately.

You can also complete the survey online. Your weblink and code are printed on the front of this postcard.

Sincerely,

Lauren Distler

Lauren Distler
MWR & MCRP Dual Degree Candidate
University of New Mexico

Dr. Caroline Scruggs
Assistant Professor
University of New Mexico

UNM SCHOOL of ARCHITECTURE & PLANNING

[DATE]

Dear Water Utility customer,

A few weeks ago, we requested your response to a survey, which will help us understand public opinions on water reuse scenarios for future consideration in Albuquerque. To the best of our knowledge, we have not yet received your completed survey. The survey will give you a chance to voice your opinion on various water reuse alternatives and other local water issues, and it will help the Albuquerque Bernalillo County Water Utility Authority (ABCWUA) plan for a reliable future water supply.

We are contacting you today to remind you about the importance of your response to the success of this study. You are among a relatively small number of residents who have the opportunity to participate in the survey, and receiving a response from everyone will help us accurately represent the voices and opinions of Albuquerque residents. Please consider completing the enclosed survey today and return it to us in the enclosed pre-paid envelope. Your response will be kept confidential and it is not linked to your name or address. If you have any questions, please contact the UNM survey team at abqwatersurvey@gmail.com or (505) 277-2283.

If you would prefer to complete the survey online, you may do so using the web address and code at the bottom of this letter.

Thank you in advance for taking the time to complete our survey! We are grateful to you for sharing your opinions, and we look forward to your response.

Sincerely,

Lauren Distler
MWR & MCRP Dual Degree Candidate
University of New Mexico

Dr. Caroline Scruggs
Assistant Professor
University of New Mexico

P.S. Don't forget, you will be entered into a raffle to win a rain barrel if you are one of the first 500 respondents to return this survey!

WEB LINK: www.surveymonkey.com/r/water[XX]
SIX DIGIT CODE: [XXXXXX]

UNM SCHOOL of ARCHITECTURE & PLANNING

[DATE]

Dear Water Utility customer,

Over the past several weeks, we have contacted you about completing a survey to help UNM researchers and the Albuquerque Bernalillo County Water Utility Authority (ABCWUA) plan for future water needs in Albuquerque. The survey gives you a chance to voice your opinion on potential water reuse scenarios for use in Albuquerque. Your response is highly valued. We will begin compiling survey results in the coming weeks, so time is running out to have your opinions included. Hearing from everyone in our sample helps to ensure that survey results are accurate.

By completing the questionnaire we sent to your address last week, you are helping ABCWUA and researchers like us answer vital questions about where our community stands on issues facing our future water supply. This is the last contact we will be sending about this questionnaire, as this phase of the project is ending. If you have any questions, please contact the UNM survey team at abqwatersurvey@gmail.com or (505) 277-2283.

If you would prefer to complete the survey online, you may do so using the web address and code at the bottom of this letter.

Many thanks again for your time and for sharing your opinions with us.

Respectfully yours,

Lauren Distler
MWR & MCRP Dual Degree Candidate
University of New Mexico

Dr. Caroline Scruggs
Assistant Professor
University of New Mexico

WEB LINK: www.surveymonkey.com/r/water[XX]
SIX DIGIT CODE: [XXXXXX]

APPENDIX B. Data Entry Guide

Data Entry – Project Assistant Guide and Task Summary

Picking Up Survey Bundles

The surveys that are ready for data entry into Survey Monkey are locked in P135 in George Pearl Hall (GPH). You will have swipe access to this room, and may work in this space if you prefer. The survey responses are bundled by version, and each bundle is marked with the number of surveys it contains. 9 hr/week equates to about 100 surveys. When picking up, please stick to your assigned version to avoid confusion in data entry:

- Version 1 – Jason Herman
- Version 2 – Corinne Fox
- Version 3 - Alyssa Latuchie
- Version 4 – Meagan Oldham

Please do not split bundles, or pick up more surveys than you know you can complete in a given timeframe.

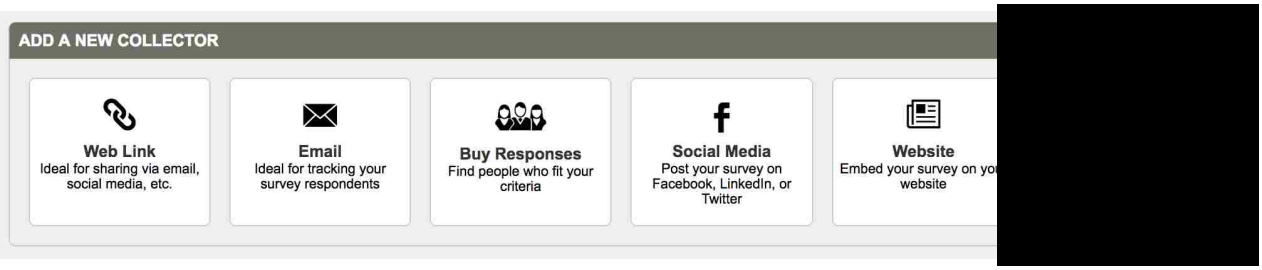
Using Manual Entry on Survey Monkey

1) Login and click the "My Surveys" tab at the top of the page.

   Login: CarolineScruggs

   PW: SA+P281006

2) Select the survey version that has been assigned to you. Select the version number with "MAIN" in the title. The other surveys listed were for the pretest.
3) Click "Collect Responses" – and you will see a list of survey collectors. You will need to create a new collector so that you can enter the data manually. You can do this by clicking the "Manual Data Entry"/ pencil icon under "Add a New Collector".



4) An empty list will appear, with a button that says "+ New Response." Pressing this will bring up a screen that is identical to the one someone will see when responding. Enter the six-digit code from the back of the survey you are entering data from and press next.
5) Complete the survey using the responses marked in the survey booklet.
6) Use a post-it to flag the last page of the paper survey if there is a comment written in the box.

Data Entry Rules

Accuracy and non-biased data entry is extremely important. Response surveys can often include questions that are left unanswered (non-response), have multiple answers to the same question (duplication), and answers that are illegible or not definitive (muddled).

Non-Response

This is simply the occurrence of a question or questions being left unanswered. Some respondents do not feel comfortable answering certain questions, skip questions on purpose or miss them for a variety of reasons. Most often, these occur in the demographics section of the survey especial with the income question. Sometimes, entire pages or sections will be left blank. If any of these occur in the paper survey, no entry should be entered into the online version.

Duplication

This type of response occurs when a survey question requires a single response or selection and the respondent marks multiple responses. Dealing with duplication is generally pretty straight-forward. Unless there is any indication that the person filling out the survey made a mistake and changed their mind (i.e. if one of the selections is scribbled out and the other is clearly the intended selection) then no response is entered into the online survey. This being said, we'd like to avoid holes in the data wherever possible. Follow the rules below for multiple responses:

- Q2: "I don't know" overrides other checked responses
- Q4: "I don't know" overrides other checked responses
- Q5: "I don't know" overrides other checked responses
- Q24: Enter the highest education level indicated.

Multiple responses to not on this list must be left blank - as a non-response.

Muddled

This type of response can occur in a number of different ways. Most often, this occurs when a response is marked in-between two of the possible responses. Questions that ask the respondent to select a number between one and five responses are marked between the numbers, for example between the 2 and the 3, with the intention that a 2.5 will be recorded. There is no way to enter a 2.5 or determine if the response should be either a 2 or a 3. These types of issues will also result in no entry being selected in the online version of the survey. Other occurrences of this type show up in questions that ask for the most common usage of something or what is of most concern. Marking between answers or circling the entire set of responses are intended to show the person uses all of them or are concerned about all of them. This evades the purpose of the question, which is looking for the specific one answer that is most common. Since again there is no way to determine an accurate response to the question, the online question will be left blank.

Overall, for muddled and duplicate answers, please use your best possible judgment!

Other comments and messages

Often surveys will be returned with comments or messages in the margins. To save time during entry, please only record comments and notes that are in designated answer boxes.

Pace yourself!

Accuracy in this case is extremely important, and data entry can be a tedious task to perform. In order to avoid mental/physical fatigue, take frequent short breaks while working.

Returning Booklets After Entry

Booklets that have been entered into Survey Monkey will be stored separately from the booklets in P135. Please contact Lauren Distler to schedule a time to drop off the booklets you are finished with. Finally, please keep track of the number of booklets that you have entered into survey monkey. Let Lauren know the quantity you have finished weekly, including the first and last codes in the bundle(s) of surveys you have completed. This will require you to keep them in the same order as when you picked them up.

Questions?

Call, text, email Lauren Distler:

443-686-1257

Distler@unm.edu

APPENDIX C. Final Survey Instrument

Community Survey

Water Scarcity and Reuse: What do you think?

Planning for our future water supply is important. Public opinion is important in shaping how water resources are managed. By responding to this survey, your opinion will be heard. It should take *between 10 and 15 minutes* of your time.

Your opinion matters- we thank you for your response

This survey was created by researchers at the University of New Mexico and is funded by the National Science Foundation

Your Thoughts on Local Issues

1) How concerned are you about the following issues in Albuquerque/Bernalillo County? *Circle your level of concern for each issue.*

Drought/ Water Shortage	Not at all concerned	Slightly concerned	Moderately concerned	Very concerned	Extremely concerned
Quality of Public Education in Local Schools	Not at all concerned	Slightly concerned	Moderately concerned	Very concerned	Extremely concerned
Population Growth and Development	Not at all concerned	Slightly concerned	Moderately concerned	Very concerned	Extremely concerned
Jobs and the Local Economy	Not at all concerned	Slightly concerned	Moderately concerned	Very concerned	Extremely concerned
Crime Rate	Not at all concerned	Slightly concerned	Moderately concerned	Very concerned	Extremely concerned
Amount Paid in Local Taxes	Not at all concerned	Slightly concerned	Moderately concerned	Very concerned	Extremely concerned
Local Drinking Water Quality	Not at all concerned	Slightly concerned	Moderately concerned	Very concerned	Extremely concerned
Amount Paid on Water Bill	Not at all concerned	Slightly concerned	Moderately concerned	Very concerned	Extremely concerned

Our Water Supply

2) In your opinion, do you think water is a limited resource in Albuquerque? *Check one.*

- ○ Yes
- ○ No
- ○ I don't know

3) From what source or sources does the Albuquerque Bernalillo County Water Utility Authority (ABCWUA) get the water it serves to customers? *Check all that apply.*

- ☐ River
- ☐ Groundwater aquifer (e.g., well water)
- ☐ I don't know
- ☐ Other

4) Do you believe that the impact of climate change on the water cycle will make it more difficult for ABCWUA to meet our community's water needs in the next 10 to 40 years? *Check one.*

- ○ Yes
- ○ No
- ○ I don't know

5) Do you believe that bottled water is safer (higher quality) than Albuquerque tap water? *Check one.*

- ○ Yes
- ○ No
- ○ I don't know

6)What type of water do you *most often* drink at home? *Check one.*

- ○ City tap water
- ○ City tap water filtered at home (e.g., sink, pitcher, or fridge units)
- ○ Water from a private well
- ○ Bottled water (e.g., 12 or 16 oz bottles)
- ○ Purified water from dispenser at a store (e.g., 3 or 5 gal containers)
- ○ Other

7) Which of the following are you currently doing at home? *Check all that apply.*

- ☐ Xeriscaped land/yard
- ☐ I don't water my land/yard
- ☐ Water saving fixtures (e.g., faucets, toilets)
- ☐ Water efficient appliances (e.g., dishwasher, washing machine)
- ☐ Rainwater harvesting (e.g., rain barrel)
- ☐ Simple conservation measures (e.g., turning off water when brushing teeth)
- ☐ None of the above

8) Generally speaking, how aware are you of water scarcity issues in New Mexico? *Circle one.*

Not at all aware	Slightly aware	Moderately aware	Very aware	Extremely aware
1	2	3	4	5

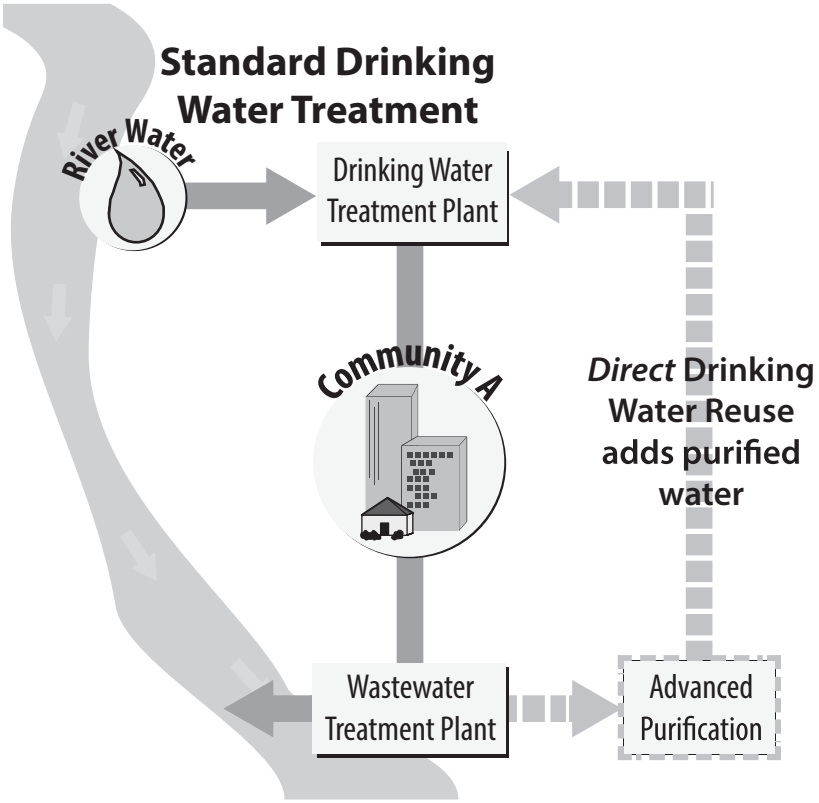
9) Are you aware of the concept of purifying wastewater and reusing it for drinking water? *Check one.*

- ○ Yes
- ○ No

On the next few pages, we'll talk about 2 different forms of water reuse. We refer to water reuse that supplements the drinking water supply as "drinking water reuse".

Direct Drinking Water Reuse

The diagram below shows how *Direct* Drinking Water Reuse would change the typical drinking water treatment process in "Community A".



All water is tested and monitored 24/7 by trained staff to meet strict water quality standards

Instead of putting treated wastewater back into the river, **some of the treated wastewater is purified to drinking water quality or better** and combined with the regular water supply.

The combined water is treated at the drinking water treatment plant and distributed to homes and businesses for all uses -- including drinking.

Direct drinking water reuse has been successfully and safely implemented in two United States cities. More facilities are being planned and built in the US.

10) How willing would you be to drink the city tap water in Community A? *Circle one.*

Refuse to Drink	Prefer to Avoid	Neutral	Generally OK	Very Willing to Drink
1	2	3	4	5

11) For what reason(s) would you be willing to drink the city tap water in Community A?
Check all that apply.

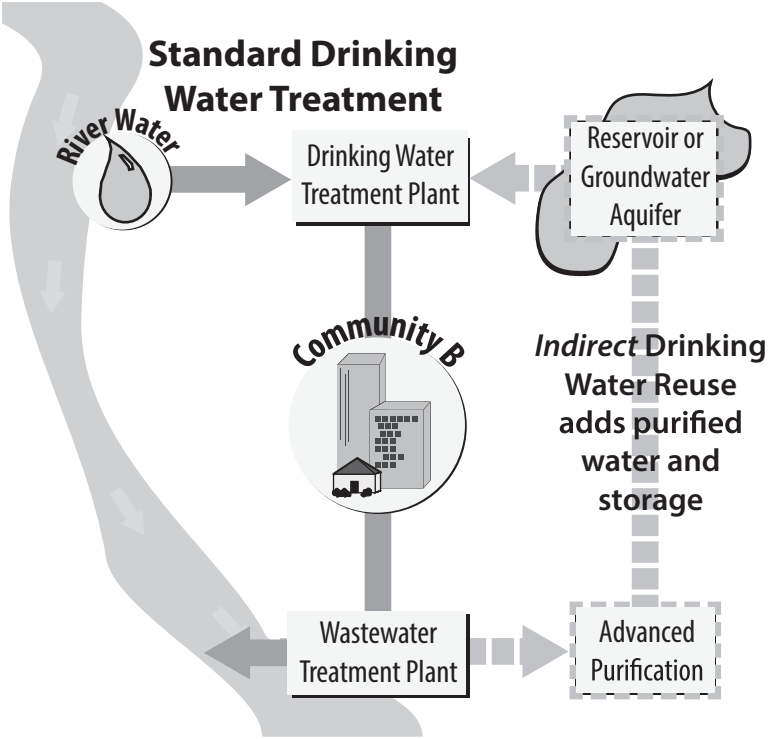
- ☐ Not applicable - I would ***not*** be willing to drink the water
- ☐ Water shortage, drought, and limited supply
- ☐ Reduces waste; efficient use of resources
- ☐ Purified water is safe to drink and is safely consumed in other US cities
- ☐ I trust the purification technologies
- ☐ Other:_____

12) What concern(s) might you have about drinking the city tap water in Community A?
Check all that apply.

- ☐ No concerns
- ☐ I don't trust the purification technologies
- ☐ I'm not confident the water is safe; health concerns
- ☐ I don't trust the government or water utility
- ☐ I would expect a bad taste/smell or discoloration of the water
- ☐ Other:_____

Indirect Drinking Water Reuse

This diagram shows that *Indirect* Drinking Water Reuse is the same as *Direct* Drinking Water Reuse, but **with one additional step -- storage in the environment.**



All water is tested and monitored 24/7 by trained staff to meet strict water quality standards

Instead of putting treated wastewater back into the river, some of the treated wastewater is purified to drinking water quality or better, **stored in a reservoir or groundwater aquifer for some time**, and then combined with the regular water supply.

The combined water is treated at the drinking water treatment plant and distributed to homes and businesses for all uses -- including drinking.

Indirect drinking water reuse has been successfully and safely implemented for many years in communities across the United States and around the world.

13) How willing would you be to drink the city tap water in Community B? *Circle one.*

Refuse to Drink	Prefer to Avoid	Neutral	Generally OK	Very Willing to Drink
1	2	3	4	5

14) For what reason(s) would you be willing to drink the city tap water in Community B?
Check all that apply.

- ☐ Not applicable - I would ***not*** be willing to drink the water
- ☐ Water shortage, drought, and limited supply
- ☐ Reduces waste; efficient use of resources
- ☐ Purified water is safe to drink and is safely consumed in other US cities
- ☐ I trust the purification technologies
- ☐ The water passes through the environment before it is treated and used again
- ☐ Other:_____

15) What concern(s) might you have about drinking the city tap water in Community B?
Check all that apply.

- ☐ No concerns
- ☐ I don't trust the purification technologies
- ☐ I'm not confident the water is safe; health concerns
- ☐ I don't trust the government or water utility
- ☐ I would expect a bad taste/smell or discoloration of the water
- ☐ Other:_____

As shown on the past few pages...

The only difference between *Direct* Drinking Water Reuse and *Indirect* Drinking Water Reuse is that *Indirect* Drinking Water Reuse includes storage of the advanced purified water in a reservoir or groundwater aquifer.

16) Based on the information provided, with which of the following statements do you *most* agree?
Check one.

- ○ I'm more willing to accept *Direct* Drinking Water Reuse
- ○ I'm more willing to accept *Indirect* Drinking Water Reuse
- ○ Both types of reuse are equally acceptable to me
- ○ Neither type of reuse is acceptable to me

17) Please indicate how much you would trust each of the following entities to provide you with accurate information on water reuse and the safety of drinking water reuse. *Circle the appropriate answer for each.*

Local Water Agency	Mostly Distrust	Somewhat Distrust	Neutral	Somewhat Trust	Mostly Trust
Elected Local Officials	Mostly Distrust	Somewhat Distrust	Neutral	Somewhat Trust	Mostly Trust
State and Federal Regulators (e.g.,NMED, EPA)	Mostly Distrust	Somewhat Distrust	Neutral	Somewhat Trust	Mostly Trust
Academic Researchers (e.g.,UNM Professors)	Mostly Distrust	Somewhat Distrust	Neutral	Somewhat Trust	Mostly Trust
Public Health Professionals (e.g.,NM Dept of Health)	Mostly Distrust	Somewhat Distrust	Neutral	Somewhat Trust	Mostly Trust
Local Media	Mostly Distrust	Somewhat Distrust	Neutral	Somewhat Trust	Mostly Trust
Environmental Nonprofit Organizations	Mostly Distrust	Somewhat Distrust	Neutral	Somewhat Trust	Mostly Trust
Friends and Family Members	Mostly Distrust	Somewhat Distrust	Neutral	Somewhat Trust	Mostly Trust

About You and Your Household[86]

Only a fraction of ABCWUA customers were randomly selected to complete this survey. Thus, **we need to know how similar you and other survey respondents are to ABCWUA customers**. Your answers to the following questions will help us to do this. All the information collected in this survey will be kept completely confidential. No individual results will be reported.

18) What is your age?

☐☐ Years

19) What is your gender? *Check one.*

- ○ Male
- ○ Female
- ○ Other

20) Do you have children younger than 18 years old living in your household? *Check one.*

- ○ Yes
- ○ No

21) Have you lived in New Mexico for most of your life? *Check one.*

- ○ Yes
- ○ No

22) Are you of Spanish/Hispanic/Latino ethnicity? *Check one.*

- ○ Yes
- ○ No

23) The previous question dealt with ethnicity while this one deals with race. Please check the race(s) you consider yourself to be. These categories are the standard categories used by the Census Bureau. *Check all that apply.*

- ☐ White
- ☐ Black or African American
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Pacific Islander
- ☐ Other

24) What is the *highest* degree or level of education you have *completed*? *Check one.*

- ○ Less than high school
- ○ Completed some high school
- ○ High school graduate/ GED
- ○ Completed some college (no degree)
- ○ Technical or Associate degree or Specialized Certificate
- ○ Bachelor's degree (BA, BS)
- ○ Master's degree (MA, MS, MBA)
- ○ Doctorate/Professional degree (PhD, JD, EdD, MD, DDS)

25) With which political party do you primarily identify? *Check one.*

- ○ Democrat
- ○ Republican
- ○ Independent
- ○ Libertarian
- ○ Green
- ○ No Affiliation

26) Which range best describes your total household income before taxes in 2016?
Check one.

- ○ Less than $14,999
- ○ $15,000 to $24,999
- ○ $25,000 to $34,999
- ○ $35,000 to $49,999
- ○ $50,000 to $74,999
- ○ $75,000 to $99,999
- ○ $100,000 to $149,999
- ○ $150,000 to $199,999
- ○ $200,000 or more

Thank you for your response!

Do you have any concerns about drinking water reuse that have not been discussed here? If so, please describe them below.

If you'd like to know more about the following topics, follow the links below or use your phone to scan the QR codes.

Drinking Water Quality Standards

https://www.epa.gov/dwstandardsregulations

Water Reuse & Advanced Purification Technologies

www.werf.org

https://watereuse.org/water-reuse-101/videos/how-reuse-works/

If the return envelope has been misplaced, please send the completed survey to:

Professor Caroline Scruggs
University of New Mexico
School of Architecture and Planning
George Pearl Hall - MSC04 2530
Albuquerque, NM 87131

Water Sources and Reliable Supplies

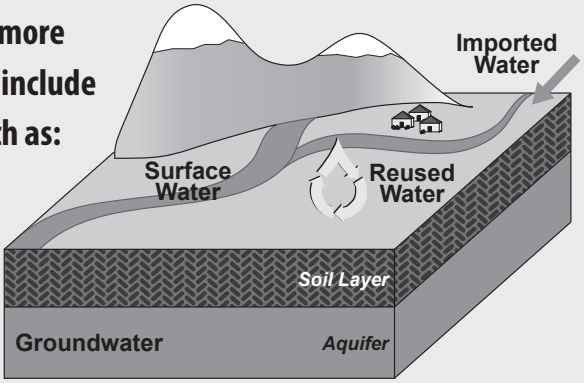
Increasing temperatures in the southwest will cause[1]:

- Increased variability of rainfall
- Increased frequency and severity of drought
- Increased evaporation from reservoirs and rivers
- Decreased snow pack, which provides ~50% of the surface water in NM

Higher Temperature → Increased Variability → Less Reliable Water Supplies

Water supplies are more reliable when they include several sources, such as:

- Surface water
- Groundwater (aquifers)
- Imported water
- Reused water



[1] Gutzler, D. S. 2013. Regional climatic considerations for borderlands sustainability. Ecosphere 4(1):7. http://dx.doi.org/10.1890/ES12-00283.1

8) Generally speaking, how aware are you of water scarcity issues in New Mexico? *Circle one.*

Not at all aware	Slightly aware	Moderately aware	Very aware	Extremely aware
1	2	3	4	5

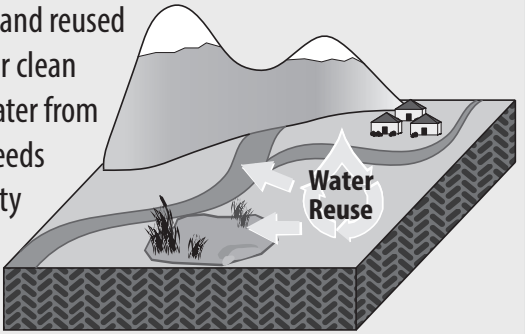
9) Are you aware of the concept of purifying wastewater and reusing it for drinking water? *Check one.*

- ○ Yes
- ○ No

On the next few pages, we'll talk about 2 different forms of water reuse. We refer to water reuse that supplements the drinking water supply as "drinking water reuse".

Environmental Benefits of Water Reuse

Wastewater can be purified and reused to help meet the demand for clean water. Advanced purified water from reuse facilities meets or exceeds federal drinking water quality standards and is suitable for all uses.



Water reuse benefits the environment by:

- Leaving more water in the environment by decreasing water diversions from sensitive ecosystems
- Increasing the availability of water to enhance stream and wetland habitats
- Replenishing groundwater supplies

8) Generally speaking, how aware are you of water scarcity issues in New Mexico? *Circle one.*

Not at all aware	Slightly aware	Moderately aware	Very aware	Extremely aware
1	2	3	4	5

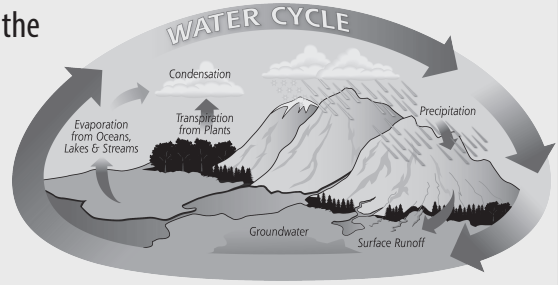
9) Are you aware of the concept of purifying wastewater and reusing it for drinking water? *Check one.*

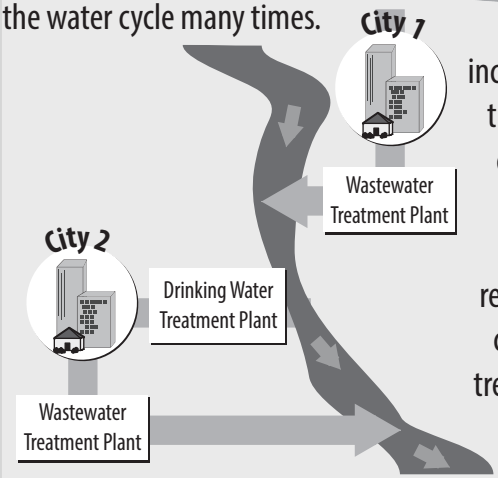
- ○ Yes
- ○ No

On the next few pages, we'll talk about 2 different forms of water reuse. We refer to water reuse that supplements the drinking water supply as "drinking water reuse".

The Urban Water Cycle

The ***water cycle*** refers to the continuous movement of water between the oceans, air, and land. Every drop of water on earth has been through the water cycle many times.





The ***urban water cycle*** incorporates human activity into the traditional cycle. For many cities located along rivers, this may involve some amount of *defacto* water reuse. *Defacto* reuse occurs when an upstream community (City 1) discharges treated wastewater into a water supply used by a downstream community (City 2).

8) Generally speaking, how aware are you of water scarcity issues in New Mexico? *Circle one.*

Not at all aware	Slightly aware	Moderately aware	Very aware	Extremely aware
1	2	3	4	5

9) Are you aware of the concept of purifying wastewater and reusing it for drinking water? *Check one.*

- ○ Yes
- ○ No

On the next few pages, we'll talk about 2 different forms of water reuse. We refer to water reuse that supplements the drinking water supply as "drinking water reuse".

APPENDIX D. Survey Data Codebook

Codebook - CREST Survey Data

Lauren N Distler

April 3, 2018

Dataset: Community Survey - Water Scarcity and Reuse: What do you think?
Document: CREST_SURVEYDATA_MARCH18.csv

Key:
Variable Name
Variable description
Data type (Continuous, Discrete, Nominal, Ordinal)
ItemValue Description

ID/General Variables

CODE
Respondent Identifier Number
Nominal
100123-555555. Random ID Number.

VERSION
Survey Version
Nominal
1. CONTROL
2. WATER SOURCES & RELIABLE SUPPLIES
3. ENVIRONMENTAL BENEFITS OF WATER REUSE
4. THE URBAN WATER CYCLE

MODE
Survey mode used
Nominal
"MAIL", "ONLINE".

ZIP
Respondant 5 digit zipcode
Nominal
87102-87123.

QUAD
Quadrant of city
Nominal
"NW", "NE", "SE", "SW".

Single Response Questions

Question 1: How concerned are you about the following issues in Albuquerque/Bernalillo County? Indicate your level of concern for each issue.

DROUGHT_CONCERN
Level of concern with drought
Ordinal
1. Not at all concerned
2. Slightly concerned
3. Moderately concerned
4. Very concerned
5. Extremely concerned

EDUCATION_CONCERN
Level of concern with quality of public education
Ordinal
1. Not at all concerned
2. Slightly concerned
3. Moderately concerned
4. Very concerned
5. Extremely concerned

POPULATION_CONCERN
Level of concern with population growth
Ordinal
1. Not at all concerned
2. Slightly concerned
3. Moderately concerned
4. Very concerned
5. Extremely concerned

JOBS_CONCERN
Level of concern with jobs and local economy
Ordinal
1. Not at all concerned
2. Slightly concerned
3. Moderately concerned
4. Very concerned
5. Extremely concerned

CRIME_CONCERN
Level of concern with crime rate
Ordinal
1. Not at all concerned
2. Slightly concerned
3. Moderately concerned
4. Very concerned
5. Extremely concerned

TAXES_CONCERN
Level of concern with amount paid in local taxes
Ordinal

1. Not at all concerned
2. Slightly concerned
3. Moderately concerned
4. Very concerned
5. Extremely concerned

WATERQUAL_CONCERN
Level of concern with quality of local drinking water
Ordinal
1. Not at all concerned
2. Slightly concerned
3. Moderately concerned
4. Very concerned
5. Extremely concerned

WATERBILL_CONCERN
Level of concern with amount paid on water bill
Ordinal
1. Not at all concerned
2. Slightly concerned
3. Moderately concerned
4. Very concerned
5. Extremely concerned

Question 2: In your opinion, do you think water is a limited resource in Albuquerque?

SCARCITY
Nominal
"Y", "N", "DK".

Question 4: Do you believe that the impact of climate change on the water cycle will make it more difficult for ABCWUA to meet our community's water needs in the next 10 to 40 years?

CLIMATE
Nominal
"Y", "N", "DK".

Question 5: Do you believe that bottled water is safer (higher quality) than Albuquerque tap water?

BOTTLED_WATER
Nominal
"Y", "N", "DK".

Question 6: What type of water do you most often drink at home?

HOME_WATER
Nominal

1. City tap water
2. City tap water filtered at home
3. Water from private well
4. Bottled water
5. Purfied water from dispenser at store
6. Other

Question 8: Generally speaking, how aware are you of water scarcity issues in New Mexico?

SCARCITY_AWARE
Ordinal
1. Not at all aware
2. Slightly aware
3. Moderately aware
4. Very aware
5. Extremely aware

Question 9: Are you aware of the concept of purifying wastewater and reusing it for drinking water?

REUSE_AWARE
Nominal
"Y", "N".

Question 10: How willing would you be to drink the city tap water in Community A?

DPR_WILL
Ordinal
1. Refuse to drink
2. Prefer to avoid
3. Neutral
4. Generally OK
5. Very willing to drink

Question 13: How willing would you be to drink the city tap water in Community B?

IPR_WILL
How willing would you be to drink the city tap water in Community B?
Ordinal
1. Refuse to drink
2. Prefer to avoid
3. Neutral
4. Generally OK
5. Very willing to drink

Question 16: Based on the information provided, with which of the following statements do you most agree? (Which type of reuse is more acceptable to you?)

MORE_WILL
Nominal
"DPR", "IPR", "BOTH", "NEITHER".

Question 17: Please indicate how much you would trust each of the following entities to provide you with accurate information on water reuse and the safety of drinking water reuse.

TRUST_ABCWUA
Level of trust in local water agency
Ordinal
1. Mostly distrust
2. Somewhat distrust
3. Neutral
4. Somewhat trust
5. Mostly trust

TRUST_LOCALGOV
Level of trust in elected local officials
Ordinal
1. Mostly distrust
2. Somewhat distrust
3. Neutral
4. Somewhat trust
5. Mostly trust

TRUST_REGULATORS
Level of trust in state and federal regulators
Ordinal
1. Mostly distrust
2. Somewhat distrust
3. Neutral
4. Somewhat trust
5. Mostly trust

TRUST_RESEARCHERS
Level of trust in academic researchers
Ordinal
1. Mostly distrust
2. Somewhat distrust
3. Neutral
4. Somewhat trust
5. Mostly trust

TRUST_PUBHEALTH
Level of trust in public health professionals
Ordinal
1. Mostly distrust

2. Somewhat distrust
3. Neutral
4. Somewhat trust
5. Mostly trust

TRUST_LOCALMEDIA
Level of trust in local media
Ordinal
1. Mostly distrust
2. Somewhat distrust
3. Neutral
4. Somewhat trust
5. Mostly trust

TRUST_NPOS
Level of trust in environmental nonprofit organizations
Ordinal
1. Mostly distrust
2. Somewhat distrust
3. Neutral
4. Somewhat trust
5. Mostly trust

TRUST_FAMILY
Level of trust in friends and family
Ordinal
1. Mostly distrust
2. Somewhat distrust
3. Neutral
4. Somewhat trust
5. Mostly trust

Multiple Response Questions

Question 3: From what source or sources does the ABCWUA get the water it serves to customers?

SOURCE_SW
Indicated surface water as a source for ABQ
Nominal
0. NO
1. YES

SOURCE_GW
Indicated ground water as a source for ABQ
Nominal
0. NO
1. YES

SOURCE_DK
Indicated that they do not know the source for ABQ
Nominal

0. NO
1. YES

SOURCE_OTHER
Indicated other as a source for ABQ
Nominal
0. NO
1. YES

Question 7: Which of the following (conservation measures) are you currently doing at home?

CONSERVE_XERI
Indicated that they xeriscape their yard to conserve
Nominal
0. NO
1. YES

CONSERVE_YARD
Indicated that they do not water their yard to conserve
Nominal
0. NO
1. YES

CONSERVE_FIXTURES
Indicated that they use water saving fixtures to conserve
Nominal
0. NO
1. YES

CONSERVE_APPLIANCES
Indicated that they use water saving appliances to conserve
Nominal
0. NO
1. YES

CONSERVE_RAINWATER
Indicated that they capture rainwater to conserve
Nominal
0. NO
1. YES

CONSERVE_SIMPLE
Indicated that they use simple techniques to conserve
Nominal
0. NO
1. YES

CONSERVE_SIMPLE
Indicated that they use simple techniques to conserve
Nominal
0. NO
1. YES

CONSERVE_NONE
Indicated that they do not conserve
Nominal
0. NO
1. YES

Question 11: For what reason(s) would you be willing to drink the city tap water in Community A?

DPR_UNWILL
Indicated that they would NOT be willing to accept DPR, no reasons to accept
0. NO
1. YES

DPR_WILL_SCARCITY
Indicated that they would be willing to accept DPR due to water shortage, drought, or limited supply.
0. NO
1. YES

DPR_WILL_WASTE
Indicated that they would be willing to accept DPR due to reduction in waste, efficient use of resources.
0. NO
1. YES

DPR_WILL_SAFE
Indicated that they would be willing to accept DPR due to purified water being safe to drink and safely consumed in other US cities.
0. NO
1. YES

DPR_WILL_TRUST
Indicated that they would be willing to accept DPR due to trust in purification technologies
0. NO
1. YES

DPR_WILL_OTHER
Indicated that they would be willing to accept DPR for another reason (WRITE IN RESPONSES)
0. NO
1. YES

Question 12: What concern(s) might you have about drinking the city tap water in Community A?

DPR_NOCONCERN
No concerns
0. NO
1. YES

DPR_CONC_TRUST

I don't trust the purification technologies
0. NO
1. YES

DPR_CONC_SAFE
I'm not confident the water is safe; health concerns
0. NO
1. YES

DPR_CONC_GOVT
I don't trust the government or water utility
0. NO
1. YES

DPR_CONC_TASTE
I would expect a bad taste/smell or discoloration of the water
0. NO
1. YES

DPR_CONC_OTHER
Other
0. NO
1. YES

Question 14: For what reason(s) would you be willing to drink the city tap water in Community B?

IPR_UNWILL
Indicated that they would NOT be willing to accept IPR, no reasons to accept
0. NO
1. YES

IPR_WILL_SCARCITY
Indicated that they would be willing to accept IPR due to water shortage, drought, or limited supply.
0. NO
1. YES

IPR_WILL_WASTE
Indicated that they would be willing to accept IPR due to reduction in waste, efficient use of resources.
0. NO
1. YES

IPR_WILL_SAFE
Indicated that they would be willing to accept IPR due to purified water being safe to drink and safely consumed in other US cities.
0. NO
1. YES

IPR_WILL_TRUST
Indicated that they would be willing to accept IPR due to trust in purification technologies
0. NO

1. YES

IPR_WILL_ENV
Indicated that they would be willing to accept IPR due to the water passing through the environment before it is treated and used again
0. NO
1. YES

Question 15: What concern(s) might you have about drinking the city tap water in Community B?

IPR_NOCONCERN
No concerns
0. NO
1. YES

IPR_CONC_TRUST
I don't trust the purification technologies
0. NO
1. YES

IPR_CONC_SAFE
I'm not confident the water is safe; health concerns
0. NO
1. YES

IPR_CONC_GOVT
I don't trust the government or water utility
0. NO
1. YES

IPR_CONC_TASTE
I would expect a bad taste/smell or discoloration of the water
0. NO
1. YES

IPR_CONC_OTHER
Other
0. NO
1. YES

Question 23: The previous question dealt with ehtnicity while this one deals with race. Please check the race(s) you consider yourself to be. These cateogries are the standard cateogries used by the Census Bureau.

RACE_WHITE
White
0. NO
1. YES

RACE_BLACK
Black

0. NO
1. YES

RACE_AI
American Indian
0. NO
1. YES

RACE_ASIAN
Asian
0. NO
1. YES

RACE_PI
Pacific Islander
0. NO
1. YES

RACE_OTHER
Other
0. NO
1. YES

Demographic Questions

AGE
Continuous
17-98

GENDER
Nominal
1. Female
2. Male
3. Other

CHILDREN
Do you have children under the age of 18 living in your household?
Nominal
1. Yes
2. No

NM_NATIVE
Have you lived in New Mexico for most of your life?
Nominal
1. Yes
2. No

ETHNICITY
Are you of Spanish/Hispanic/Latino ethnicity?
Nominal
1. Yes
2. No

EDUCATION
What is the highest degree or level of education you have completed?
Ordinal
1. Less than highschool
2. Completed some highschool
3. High school graduate/ GED
4. Completed some college (no degree)
5. Technical or associate degree or specialized certificate
6. Bachelors degree (BA, BS)
7. Masters degree (MA, MS, MBA)
8. Doctorate/Professional degree (PhD, JD, EdD, MD, DDS)

EDUCATION_CAT
Ordinal
"L", "M", "H"
L = Up to high school graduate
M = Up to bachelors
H = Above bachelors

POLITICAL
With which political party do you identify?
Nominal
"DEM","REP","IND","LIB","GR","O".
DEM = Democrat
REP = Republican
IND = Independent
LIB = Libertarian
GR = Green
O = Other

INCOME
Which range best describes your total household income before taxes in 2016?
Discrete
1. Less than $14,999
2. $15,000 - $24,999
3. $25,000 - $34,999
4. $35,000 - $49,999
5. $50,000 - $74,999
6. $75,000 - $99,999
7. $100,000 - $149,999
8. $150,000 - $199,999
9. $200,000 or more

APPENDIX E. Code for mult.freq.table Function

APPENDIX E: Code for multi.freq.table Function

Lauren N Distler

6/5/2018

```
multi.freq.table = function(DATA, sep="", dropzero=FALSE, clean=TRUE) {

  counts = data.frame(table(DATA))
  N = ncol(counts)
  counts$Combn = apply(counts[-N] == 1, 1,
                       function(x) paste(names(counts[-N])[x],
                                         collapse=sep))
  if (isTRUE(dropzero)) {
    counts = counts[counts$Freq != 0, ]
  } else if (!isTRUE(dropzero)) {
    counts = counts
  }
  if (isTRUE(clean)) {
    counts = data.frame(Combn = counts$Combn, Freq = counts$Freq)
  }
  counts
}

OUTPUT <-multi.freq.table(DATA[-1], sep="-")

write.csv(OUTPUT, 'OUTPUT.csv')
```

APPENDIX F. Code for Ordinal Logistic Regression Models

APPENDIX F: Code for Ordinal Logistic Regression Models

Lauren N Distler

6/12/2018

```
library('tidyverse')
library('RColorBrewer')
library('gridExtra')
data <- read_csv('../DATA/CREST_SURVEYDATA_MARCH18.csv')
#DROP OTHER GENDER (not enough data)
data$GENDER[data$GENDER == 'O'] <- NA
#data <- subset(data, !(GENDER=='O'))
#MAKE INCOME QUANTITATIVE
inc_f <- function(x){
  y <- rep(NA, length(x))
  for(i in 1:length(x)){
    if(!is.na(x[i])){
      if(x[i]==1) y[i] <- 15
      if(x[i]==2) y[i] <- 20
      if(x[i]==3) y[i] <- 30
      if(x[i]==4) y[i] <- 40
      if(x[i]==5) y[i] <- 62.5
      if(x[i]==6) y[i] <- 87.5
      if(x[i]==7) y[i] <- 125
      if(x[i]==8) y[i] <- 175
      if(x[i]==9) y[i] <- 200
    }
  }
  return(y)
}
data$INCOME_QUANT <- inc_f(data$INCOME)
#MAKE BINARY VERSION
data$VERSION_BIN <- (data$VERSION > 1)

data$VERSION_FACTOR <- cut(data$VERSION, breaks=c(0,1,2,3,4),labels=c("ONE","TWO","THREE","FOUR"))
table(data$VERSION_FACTOR)

#GROUP POLITICS INTO DEM REP OTH
data$POLITICAL[data$POLITICAL == 'O'] <- 'NONE'
data$POLITICAL_GROUPED <- data$POLITICAL
data$POLITICAL_GROUPED[which(!(data$POLITICAL %in% c('DEM', 'REP', 'NONE')))] <- 'OTH'

# Group IPR and DPR variables and make them ordered
data$IPR_WILL_3 <- rep('Neutral', length(data$IPR_WILL))
data$IPR_WILL_3[data$IPR_WILL > 3] <- 'Willing'
data$IPR_WILL_3[data$IPR_WILL < 3] <- 'Unwilling'
data$IPR_WILL_3 <- factor(data$IPR_WILL_3, ordered=T,
levels=c('Unwilling', 'Neutral', 'Willing'))

data$IPR_WILL_3 <-factor(data$IPR_WILL_3, ordered = is.ordered(data$IPR_WILL_3),levels = c('Unwilling',
```

```
data$IPR_WILL_3

data$DPR_WILL_3 <- rep('Neutral', length(data$DPR_WILL))
data$DPR_WILL_3[data$DPR_WILL > 3] <- 'Willing'
data$DPR_WILL_3[data$DPR_WILL < 3] <- 'Unwilling'
data$DPR_WILL_3 <- factor(data$DPR_WILL_3, ordered=T,
levels=c('Unwilling', 'Neutral', 'Willing'))

data$DPR_WILL_3 <-factor(data$DPR_WILL_3, ordered = is.ordered(data$DPR_WILL_3),levels = c('Unwilling',
data$DPR_WILL_3

#Select columns
predictors <- subset(data, select=c(GENDER, AGE, POLITICAL_GROUPED,
EDUCATION_CAT, INCOME_QUANT, NM_NATIVE, REUSE_AWARE, VERSION_BIN))

### CLM Models
library('ordinal')
IPR_fit <- clm(data$IPR_WILL_3 ~., data=predictors)
summary(IPR_fit)

#DPR_fit <- clm(as.factor(data$DPR_WILL_3)~., data=predictors)
DPR_fit <- clm(data$DPR_WILL_3 ~., data=predictors)
IPR_fit <- clm(data$IPR_WILL_3~., data=predictors)
summary(IPR_fit)

DPR_fit <- clm(data$DPR_WILL_3~., data=predictors)
summary(DPR_fit)


#DROP NA's AND PERFORM MODEL SELECTION WITH AIC
ind <- as.numeric(IPR_fit$na.action)
predictors_ipr <- predictors[-ind,]
y_ipr <- data$IPR_WILL_3[-ind]
temp <- clm(y_ipr~., data=predictors_ipr)
IPR_fit_step <- step(temp)
summary(IPR_fit_step)

write.csv(data.frame(summary(IPR_fit_step)$coefficients), file="IPRcoefficients.csv")

ind <- as.numeric(DPR_fit$na.action)
predictors_dpr <- predictors[-ind,]
y_dpr <- data$DPR_WILL_3[-ind]
temp <- clm(y_dpr~., data=predictors_dpr)
DPR_fit_step <- step(temp)
summary(DPR_fit_step)

write.csv(data.frame(summary(DPR_fit_step)$coefficients), file="DPRcoefficients.csv")


# PREDICT PROBABILIY OF ACCEPTANCE BASED ON VERSION

myipr <- clm(data$IPR_WILL_3 ~ data$VERSION_BIN)
myipr
mydpr <- clm(data$DPR_WILL_3 ~ data$VERSION_BIN)
```

```
mydpr

#MODELS WITH ONLY EDUCATIONAL MATERIALS
ipr_fit_version <- clm(IPR_WILL_3~VERSION_BIN, data=data)
summary(ipr_fit_version)
dpr_fit_version <- clm(DPR_WILL_3~VERSION_BIN, data=data)
summary(dpr_fit_version)
#ESTIMATE PROBABILITIES (IPR)
  #Method 1 - using the formulas
  pars <- ipr_fit_version$coefficients #parameters
  ipr_pi_edu <- rep(NA, 3)
  ipr_pi_edu[1] <- exp(pars[1] - pars[3])/(1+exp(pars[1]-pars[3]))
  ipr_pi_edu[2] <- exp(pars[2] - pars[3])/(1+exp(pars[2] - pars[3])) - pi1_edu
  ipr_pi_edu[3] <- 1 - pi2_edu - pi1_edu

  #Method 2 - using predict function
  ipr_pred <- predict(ipr_fit_version, newdata=data.frame(VERSION_BIN=c(T,F)),
  interval=T, se.fit=T, level=0.95)
ipr_pred
  dpr_pred <- predict(dpr_fit_version, newdata=data.frame(VERSION_BIN=c(T,F)),
  interval=T, se.fit=T, level=0.95)
dpr_pred

  par(mfrow=c(1,2))
  plot(1:3, ipr_pred$fit[1,], type='o', col='dodgerblue', pch=16, ylim=c(0.1, 0.6),
  ylab='Probability', xlab='Willingness to Accept IPR', xaxt='n')
  axis(1, 1:3, c('Unwilling', 'Neutral', 'Willing'))
  polygon(c(1:3, 3:1), c(ipr_pred$lwr[1,], rev(ipr_pred$upr[1,])),
  lty=0, col=adjustcolor('dodgerblue', alpha.f=0.1))
  lines(1:3, ipr_pred$fit[2,], type='o', col='firebrick', pch=16)
  polygon(c(1:3, 3:1), c(ipr_pred$lwr[2,], rev(ipr_pred$upr[2,])),
  lty=0, col=adjustcolor('firebrick', alpha.f=0.1))
  grid()
  legend('topleft', c('Educational Materials', 'Control Group'), fill=c('dodgerblue', 'firebrick'), bty=

  plot(1:3, dpr_pred$fit[1,], type='o', col='dodgerblue', pch=16, ylim=c(0.1, 0.6),
  ylab='Probability', xlab='Willingness to Accept DPR', xaxt='n')
  axis(1, 1:3, c('Unwilling', 'Neutral', 'Willing'))
  polygon(c(1:3, 3:1), c(dpr_pred$lwr[1,], rev(dpr_pred$upr[1,])),
  lty=0, col=adjustcolor('dodgerblue', alpha.f=0.1))
  lines(1:3, dpr_pred$fit[2,], type='o', col='firebrick', pch=16)
  polygon(c(1:3, 3:1), c(dpr_pred$lwr[2,], rev(dpr_pred$upr[2,])),
  lty=0, col=adjustcolor('firebrick', alpha.f=0.1))
  grid()()
  legend('topleft', c('Educational Materials', 'Control Group'), fill=c('dodgerblue', 'firebrick'), bty=
```

REFERENCES

Albuquerque Bernalillo County Water Utility Authority. (2016). *Water 2120 : Securing our Water Future*.

Brookshire, D., Gupta, H., & Matthews, O. P. (2013). *Water policy in New Mexico: addressing the challenge of an uncertain future*. Routledge.

Chan, A. (2014). *The Future of Direct Potable Reuse in California: Overcoming Public Acceptance Barriers*. University of San Francisco. Retrieved from http://repository.usfca.edu/cgi/viewcontent.cgi?article=1101&context=capstone

Corum, L. (2015). Water Reuse - Finding the Holy Grail. *Water Efficiency*. Retrieved from https://foresternetwork.com/water-efficiency-magazine/we-water/water-reuse-we-water/water-reuse-finding-the-holy-grail/

Crook, J. (2010). *Regulatory aspects of direct potable reuse in California*. National Water Research Institute.

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). Internet, phone, mail, and mixed-mode surveys: the tailored design method. John Wiley & Sons.

Dolnicar, S., & Hurlimann, A. (2011). Water alternatives—who and what influences public acceptance? *Journal of Public Affairs*, *11*(1), 49–59.

Dolnicar, S., Hurlimann, A., & Nghiem, L. D. (2010). The effect of information on public acceptance--the case of water from alternative sources. *Journal of Environmental Management*, *91*(6), 1288–1293.

Duong, K., & Saphores, J.-D. M. (2015). Obstacles to wastewater reuse: an overview. *Wiley Interdisciplinary Reviews: Water*, *2*(3), 199–214.

Fielding, K. S., Gardner, J., Leviston, Z., & Price, J. (2015). Comparing public perceptions of alternative water sources for potable use: the case of rainwater, stormwater, desalinated water, and recycled water. *Water Resources Management*, *29*(12), 4501–4518.

Garcia-Cuerva, L., Berglund, E. Z., & Binder, A. R. (2016). Public perceptions of water shortages, conservation behaviors, and support for water reuse in the US. *Resources, Conservation and Recycling*, *113*, 106–115.

Gerrity, D., Pecson, B., Trussell, R. S., & Trussell, R. R. (2013). Potable reuse treatment trains throughout the world. *Journal of Water Supply: Research and Technology-AQUA*, *62*(6), 321–338.

Gu, Q., Chen, Y., Pody, R., Cheng, R., Zheng, X., & Zhang, Z. (2015). Public perception and acceptability toward reclaimed water in Tianjin. *Resources, Conservation and Recycling*, *104*, 291–299.

Haarhoff, J., & der Merwe, B. (1996). Twenty-five years of wastewater reclamation in Windhoek, Namibia. *Water Science and Technology*, *33*(10–11), 25–35.

Hartley, T. W. (2006). Public perception and participation in water reuse. *Desalination*, *187*(1Hartley, T. W. (2006). Public perception and participation in water reuse.

Desalination, 187(1), 115–126.), 115–126.

Hurlimann, A., & Dolnicar, S. (2010). When public opposition defeats alternative water projects--the case of Toowoomba Australia. *Water Research*, *44*(1), 287–297.

Ishii, S. K. L., Boyer, T. H., Cornwell, D. A., & Via, S. H. (2015). Public Perceptions of Direct Potable Reuse in Four US Cities. *JOURNAL AWWA*, *107*, 11.

Jansen, H. P., Stenstrom, M. K., & De Koning, J. (2007). Development of indirect potable reuse in impacted areas of the United States. *Water Science and Technology*, *55*(1–2), 357–366.

Krueger, R. A., & Casey, M. A. (2000). Focus groups: a practical guide for applied research.

Leverenz, H. L., Tchobanoglous, G., & Asano, T. (2011). Direct potable reuse: a future imperative. *Journal of Water Reuse and Desalination*, *1*(1), 2. http://doi.org/10.2166/wrd.2011.000

Lohman, L. C. (1987). Potable wastewater reuse can win public support. In *Proceedings of Water Reuse Symposium IV* (pp. 1029–1046).

Macpherson, L., & Slovic, P. (2011). *Talking About Water: Vocabulary and Images that Support Informed Decisions about Water Recycling and Desalination*.

Macpherson, L., & Snyder, S. A. (2013). *Downstream: Context, understanding, acceptance: Effect of prior knowledge of unplanned potable reuse on the acceptance of planned potable reuse*. WateReuse Research Foundation.

McCullagh, P. (1980). Regression models for ordinal data. *Journal of the Royal Statistical Society. Series B (Methodological)*, 109–142.

Millan, M., Tennyson, P. A., & Snyder, S. A. (2015). *Model communication plans for increasing awareness and fostering acceptance of direct potable reuse*. WateReuse Research Foundation.

National Research Council. (2012). *Water reuse: potential for expanding the nation's water supply through reuse of municipal wastewater*. National Academies Press.

Orange County Water District. (n.d.). About GWRS. Retrieved January 18, 2018, from https://www.ocwd.com/gwrs/about-gwrs/

Ormerod, K. J. (2016). Illuminating elimination: public perception and the production of potable water reuse. *Wiley Interdisciplinary Reviews: Water*, *3*(4), 537–547.

Ormerod, K. J., & Scott, C. A. (2012). Drinking wastewater: Public trust in potable reuse. *Science, Technology & Human Values*, 162243912444736.

Rozin, P., Haddad, B., Nemeroff, C., & Slovic, P. (2015). Psychological aspects of the rejection of recycled water: Contamination, purification and disgust. *Judgment and Decision Making*, *10*(1), 50.

Russell, S., & Hampton, G. (2006). Challenges in understanding public responses and providing effective public consultation on water reuse. *Desalination*, *187*(1), 215–227.

Scruggs, C. E., & Thomson, B. M. (2017). Opportunities and challenges for direct

potable water reuse in arid inland communities. *Journal of Water Resources Planning and Management*, *143*(10), 4017064.

Stoutenborough, J. W., & Vedlitz, A. (2014). Public attitudes toward water management and drought in the United States. *Water Resources Management*, *28*(3), 697–714.

Tchobanoglous, G., Leverenz, H., Nellor, M., & Crook, J. (2011). *Direct Potable Reuse: A Path Forward*. *WateReuse Research*.

Thacher, J., Marsee, M., Pitts, H., Hansen, J., Chermak, J., & Thomson, B. (2011). Assessing customer preferences and willingness to pay: a handbook for water utilities. *Water Environment Federation. Denver, Colorado*.

U.S. Census Bureau. (2014). *Presence of a Computer and Type of Internet Subscription in Household*. *American Community Survey 1-Year Estimates, B28003*. Retrieved from http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_14_1YR_B28003&prodType=table

United States Environmental Protection Agency. (2012). *Guidelines for Water Reuse*. Washington, D.C.

Water Matters: Water Articles Written for Members of the New Mexico State Legislature and the Public. (2015). *Utton Transboundary Resource Center, UNM*.