Arid Inland Community Survey on Water Knowledge, Trust, and Potable Reuse. II: Predictive Modeling

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Abstract: Demographic and contextual factors have been shown to influence acceptance of water reuse but have not been adequately studied in an arid inland context. The authors conducted a survey of 4,000 water utility customers in Albuquerque, New Mexico, (response rate $= 46\%$) on acceptance of two potable reuse scenarios, trust in institutions, water scarcity–related topics, and demographic information. Using ordered logistic regression models, the predictive power of demographic factors on acceptance of direct potable reuse (DPR) and indirect potable reuse (IPR) was investigated. It is demonstrated that demographic data can be used to predict probabilities of potable reuse acceptance with reasonable accuracy. Chi-square tests of independence were then used to further examine the relationships among less-accepting demographic groups and their levels of trust in institutions, prior awareness of potable reuse, and knowledge of water scarcity in the region. This study intends to fill knowledge gaps related to arid inland perspectives on potable water reuse and related topics, and proposes an approach to enable creation of inclusive public dialogue and design of tailored education and outreach programming.
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Effect of Demographic and Contextual Factors on Acceptance of Water Reuse and Contributions of the Present Study

As discussed in Part I of this study (Distler and Scruggs 2020a), community surveys help to provide an understanding of what a population knows and thinks about water-related issues and potable water reuse. Ideally, survey data can be used to inform a meaningful public dialogue about options for meeting future potable water demands (Stenekes et al. 2006) and in designing effective education and outreach programming (Wegner-Gwidt 1991). Several studies have been conducted, primarily in Australia and the US, to understand public perceptions of water reuse, and most included an analysis of public acceptance based on demographic and other variables (e.g., Garcia-Cuerva et al. 2016; Ishii et al. 2015; Millan et al. 2015; Miller and Buys 2008; Po et al. 2005). However, although the studies generally indicated that demographics influence acceptance, the findings were not always in agreement regarding which demographic variables were associated with support or lack of support for potable reuse.

For example, although several studies suggested that being male and/or having a higher education level positively influence attitudes toward water reuse, they do not necessarily agree on whether it is older or younger people who are more accepting (Dolnicar et al. 2011). The reason for this is likely because individual perceptions are shaped by local context (Ormerod and Scott 2012). Context can include numerous nondemographic factors such as the authorities and institutions that initiate discussions about water reuse, public trust in those authorities, knowledge and information on water resource topics, prior knowledge of or experience with water reuse, presence or absence of previous public dialogue or debate about potable reuse, climate conditions, and history of water scarcity in the community (Dolnicar et al. 2011; Macpherson and Snyder 2013; Ormerod and Scott 2012).

Hurlimann and Dolnicar (2010) argued that more research is needed on how contextual differences impact public knowledge and perceptions in order to better understand the reasons behind public attitudes toward water from alternative sources. The relationships among demographic and contextual variables and acceptance of potable reuse have yet to be explored for a small- and medium-sized arid inland community context, and these relationships may be different from what has been reported for the large coastal context.

This paper uses findings from the first large-scale survey on public attitudes toward potable water reuse in an arid inland US community to fill knowledge gaps regarding the demographic and contextual factors that influence acceptance in an arid inland context. Furthermore, different from previous research on the factors influencing acceptance of potable reuse, this study also involved creation of a model to investigate the predictive power of numerous demographic variables on acceptance of two potable reuse scenarios, and then used the results of the model to further investigate contextual reasons (e.g., lack of trust in certain entities) that explain why certain groups might not accept potable reuse. Based on previous studies, it is hypothesized that indirect potable reuse (IPR) would be accepted at a higher rate than direct potable

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reuse (DPR), that people identifying as female, older individuals, and those with children at home would be less likely to accept both water reuse scenarios, and that those who have obtained a higher level of education would be more likely to accept both water reuse scenarios (Dolnicar et al. 2011; Garcia-Cuerva et al. 2016; Millan et al. 2015). It is also hypothesized that long-term New Mexico residents would be more accepting of potable reuse based on the fact that their surroundings reflect a dry, desert environment, and research has shown that context influences acceptance (Ormerod and Scott 2012).

This study is intended to fill knowledge gaps related to arid inland perspectives on potable water reuse and related topics and proposes an approach to enable creation of inclusive public dialogue and design of tailored education and outreach programming. The focus of this paper is the influence of demographic and contextual factors on acceptance of potable reuse. Detailed information about the basic survey results is the subject of the companion paper Arid Inland Community Survey on Water Knowledge, Trust and Potable Reuse. I: Description of Findings (Distler and Scruggs 2020a).

Methods

The survey instrument described in Part I contained 26 questions, including a series of nine demographic questions. The demographic questions collected information on the following characteristics of respondents: age, gender identity, whether the respondent had children under the age of 18 at home, whether the respondent lived in New Mexico for most of their life, ethnicity, race, education level, political affiliation, and annual household income. These questions were placed at the end of the survey due to their potentially sensitive nature (Thacher et al. 2011). All methods for this study were discussed in Part I except for those regarding statistical modeling and predictive accuracies, which are described in the following paragraphs.

Ordered logistic regression was used to model the predictive power of various demographic variables on acceptance of DPR and IPR. The survey instrument assessed respondents' willingness to accept potable reuse using an ordinal or Likert-type scale with five categories, including a neutral middle category. Many traditional classification methods (e.g., logistic regression, support vector machines, and random forests) are known as binary classifiers, which means they decide between only two categories. However, partitioning the used Likert-type scale into two categories, i.e., willing to accept and unwilling to accept, was not sensible because it was unclear to which of the two categories the neutral response option belonged, and the results would be sensitive to this somewhat arbitrary choice. Although traditional classification methods can be extended to handle multiple nominal categories, they usually fail to account for the ordinal nature of the response variable.

Cumulative link models (CLMs) are designed to address this problem. In particular, ordered logistic regression is a member of the CLM class when a proportional log-odds assumption is made (McCullagh 1980; Walker and Duncan 1967). This assumption, which assumes that the effects of explanatory variables are additive across the ordered categories on the log-odds scale, was visually assessed using R version 1.0.136 software for each of the variables included in the models. It was determined that the proportional log-odds assumptions were reasonably met. Therefore, ordered logistic regression was used to predict the probability that an individual, given a certain set of features, would fall into one of several ordered categories of acceptance. Further details on estimation and interpretation of model parameters and the use of the model for prediction are presented in Fig. S1.

For a fixed set of explanatory variables, parameter values of the ordered logistic regression were obtained using maximum likelihood estimation. A remaining issue was to establish the criteria by which explanatory variables would be retained in the final model. Many criteria exist [e.g., F-test, Akaike information criteria (AIC), R-squared, adjusted R-squared, and Mallows C_p] for evaluating the quality of a statistical model. This study utilized a stepwise procedure, choosing the AIC as the measure of quality. This procedure involves sequentially adding and removing variables in an attempt to maximize the quality of the model. As a measure of quality, AIC rewards the model for having high likelihood but includes a penalty for the number of explanatory variables included the model. This produces a model with high explanatory power but avoids the inclusion of nonsignificant features.

Once the explanatory variables were selected for the final models, a leave-one-out cross-validation (LOOCV) procedure was performed to assess the predictive capabilities of the model. The basic idea behind LOOCV is to remove a single subject from the data set and fit the statistical model on the remaining data. This model is then used to predict the left-out subject's level of acceptance of potable reuse and compare it with the subject's actual response. This procedure can be repeated for every subject in the model to assess the overall accuracy. Because the ordered logistic regression model returns a set of probabilities, the predicted category (e.g., unwilling, neutral, or willing to accept potable reuse) is taken to be the category with the highest probability. Applying this procedure, LOOCV accuracies of 49.5% and 59.8% for DPR and IPR, respectively, were obtained.

Although these accuracies are only around or slightly above 50%, it is unreasonable to expect a predictive model to perform much higher based on demographic features alone. The ordered logistic regression model cannot predict with high accuracy whether or not an individual will accept, but one can accurately predict the probability that they will accept. Put another way, the ordered logistic regression model is good for predicting willingness for groups of individuals but not necessarily for individuals themselves. This idea is explored further in the "Results and Discussion" section, where evidence is provided to support the claim that the proposed model accurately predicts the willingness of groups (Fig. 2). To show that the ordered logistic regression and the use of demographic information provides significant predictive power, the results are compared with a simple probabilistic classifier (which makes no use of the demographic information), and it is shown that the ordered logistic regression model is superior. Details on this procedure can be found in Fig. S2.

Results and Discussion

A conservative estimate of the survey's response rate was 45.8%, with a total of 1,831 responses. This estimate is simply the number of responses divided by the total number of surveys sent (4,000) and does not take into account recipients of unknown eligibility, i.e., those who were not contacted because the surveys were returned by the postal service due to issues such as an incorrect address or vacant home (Thacher et al. 2011). It was estimated by University of New Mexico (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 the undeliverable surveys from the total number sent for an adjusted response rate of 48.2%. Nonetheless, the demographic data of nonrespondents and the population of interest at large are not available for comparison with the data of survey respondents.

Selected Basic Survey Results

Although the survey instrument had a total of 26 questions, this section introduces only the results of questions most pertinent to the demographic-related analyses that are the focus of this paper. Among the first questions asked in the survey were those related to water scarcity and climate change. Question 2 asked respondents if they "believe water is a limited resource in Albuquerque." Eighty-one percent of respondents answered "Yes," 10% answered "No," and 7% answered "I don't know" (the percentages do not add to 100% due to nonresponses). Then, after a series of questions about home water use and prior to questions related to potable water reuse, Question 9 asked respondents if they were "aware of the concept of purifying wastewater and reusing it for drinking water." Respondents could select either "Yes" or "No." This question was added to determine whether the respondent had knowledge of potable reuse prior to taking the survey because prior knowledge of reuse has been shown to impact acceptance (Dolnicar et al. 2011; Macpherson and Snyder 2013). Results indicated that 68.5% of respondents had a prior awareness of potable reuse.

In comparison, Millan et al.'s (2015) survey of 1,200 southern California voters found that a total of 73% of respondents were "very" or "somewhat familiar with the concept of recycled water," and a total of 27% were "not too familiar" or "not at all familiar." Using Fisher's exact test, the difference between prior awareness in the New Mexico and California populations (4.5%) was found to be statistically significant ($p = 0.008$). It is not surprising that Millan et al.'s (2015) respondents were more familiar given that the surveyed population had previous experience with potable reuse projects (e.g., the failed attempt by San Diego, California, to implement IPR in the 1990s), whereas there has been minimal public dialogue related to potable reuse in Albuquerque.

Next, after an introduction to each hypothetical potable reuse scenario (i.e., DPR in Community A and then IPR in Community B), respondents were asked about their willingness to drink city tap water in each community. Fig. 1 shows the breakdown of responses for both scenarios on a 5-point Likert-type scale.

As expected, respondents were more willing to drink the tap water in a community that implemented IPR rather than DPR. There was also a sizable "Neutral" category of about 21% for both scenarios. To conduct analyses on these data, the 5-point scale was collapsed into 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. Grouping the response options in this way showed that the "Willing" category captured the majority of respondents for both DPR and IPR, with 47% and 54% of respondents, respectively.

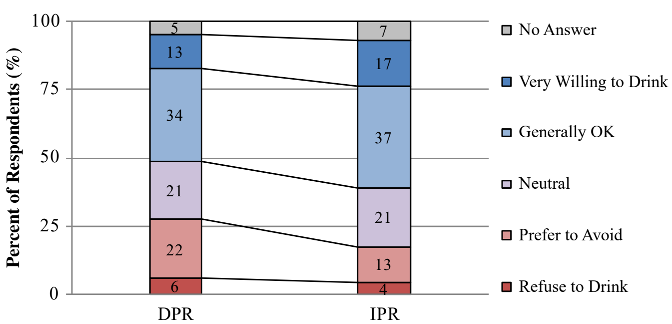

Fig. 1. Breakdown of acceptance for each hypothetical potable reuse scenario, DPR and IPR.

Although these results indicate that respondents are generally willing to accept both types of potable reuse, DPR is clearly the less favored option, with 28% in the collapsed "Unwilling" category, compared with 18% for IPR. Looking at the data another way, 26% of respondents indicated that they were more willing to accept IPR than DPR compared with only 6% who were more willing to accept DPR than IPR. In comparison, after exposure to similar educational information, 54% and 31% of Millan et al.'s (2015) southern California voters were either "somewhat" or "strongly" opposed to DPR and IPR, respectively. Even more striking were the percentages of California voters who were only strongly opposed: 36% for DPR and 18% for IPR, which were far higher than the percentages (5.7% and 4.2%, respectively) for Albuquerque Bernalillo County Water Utility Authority (ABCWUA) respondents.

The last survey question prior to the demographic questions asked respondents about their level of trust in eight different entities to provide accurate information on water reuse. Previous studies have found that distrust of entities responsible for community water supplies (such as the local government or water agency) is a factor that negatively impacts acceptance of reuse (Dolnicar et al. 2011; Ishii et al. 2015; Ormerod and Scott 2012). Respondents were given a list of entities and asked to indicate their level of trust for each on the following scale: "Mostly Distrust," "Somewhat Distrust," "Neutral," "Somewhat Trust," or "Mostly Trust." Fig. S3 shows the detailed results of this survey question, ranked by the largest sum of "Mostly Trust" and "Somewhat Trust" categories to the smallest. In further analyses of these data, the bottom two categories were grouped into "Distrust" and the top two categories into "Trust."

The results showed that 51% of respondents distrusted elected local officials, 40% of respondents distrusted the local media, and 28% distrusted state and federal regulators, such as the New Mexico Environment Department or the Environmental Protection Agency. Among the most trusted entities were academic researchers and public health professionals, with 61% of respondents falling into either the "Mostly Trust" or "Somewhat Trust" categories. With the exception of the results for regulators, these results align with those of other studies, echoing that trust is generally lowest in elected officials and media outlets, and highest in those with knowledge in scientific fields, such as public health departments or academic researchers (Ishii et al. 2015; Millan et al. 2015; Ormerod and Scott 2012). The local water agency, ABCWUA, and environmental nonprofit organizations (NPOS) were moderately trusted, with 47% and 49%, respectively, of respondents indicating that they trusted these entities.

The results of the nine survey questions related to demographics were summarized in Table S1 in Part I of this study, along with the frequency and rate of nonresponse for each survey question. As indicated in Part I's Table S1, the survey's final question, which collected information on annual household income, was apparently quite sensitive, with nearly 10% of respondents electing not to respond.

Predicting Willingness to Accept Potable Reuse Using Demographic Factors

Using the demographic data collected by the survey, an ordered logistic regression model was fit to examine the predictive power of demographic variables on acceptance of each reuse scenario. The number of observations included for both the DPR and IPR models was equal to the total number of respondents with complete data for all variables included in each model. It was attempted to maximize the number of observations for each model while retaining variables useful for prediction. In initial drafts of the models, the income

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Table 1. Summary of model coefficients predicting willingness to drink DPR and IPR water

Variable	Estimate	Standard error	p-value
DPR (number of observations = 1,565)			
Male	0.321	0.097	<0.001
Spanish/Hispanic/Latino ethnicity	−0.206	0.111	0.062
College degree	−0.131	0.134	0.326
High school degree or less	−0.541	0.166	0.001
Some college	−0.538	0.126	<0.001
Long-term New Mexico resident	0.278	0.111	0.012
IPR (number of observations = 1,525)			
Male	0.315	0.106	0.003
Children at home	−0.192	0.136	0.157
Age	−0.006	0.004	0.150
Spanish/Hispanic/Latino ethnicity	−0.327	0.122	0.008
Independent/no affiliation	−0.358	0.125	0.004
Other affiliation	−0.143	0.295	0.628
Republican	0.028	0.137	0.836
College degree	−0.079	0.147	0.588
High school degree or less	−0.674	0.177	<0.001
Some college	−0.538	0.136	<0.001
Long-term New Mexico resident	0.329	0.118	0.005

variable was included in the model parameters but was not retained by the AIC. Due to the lack of usefulness for prediction and the large number of missing data associated with the variable (179 nonresponses), the income variable was dropped from the analyses. Future work, either with this data set or with similar surveys, could consider treating the missing data with imputation methodology (Brick and Kalton 1996). The variables retained by the DPR and IPR models, including the magnitude and direction of their predictive power, associated standard error values, and p-values are reported in Table 1.

Variables with more than two categories that were retained by the model should be interpreted in comparison with the omitted category, i.e., the categories shown in Table S1 of Part I of this study that are not given in Table 1. For example, for the education level variable, the omitted category was "Advanced Degree," meaning that the magnitude and direction of coefficients for the other educational groups should be interpreted in comparison with "Advanced Degree." The omitted category for the political affiliation variable was "Democrat." The impact of a variable on willingness to accept is determined by the sign of the value in Table 1's "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 to accept DPR or IPR.

For both DPR and IPR, if a respondent was male or a long-term New Mexico resident, they were more likely to fall into the "Willing" category. Compared with respondents with advanced degrees, those falling into the lower education categories were less likely to accept both types of reuse. Additionally, those of Spanish, Hispanic, or Latino ethnicity were less likely to be willing to accept each reuse scenario. For IPR, several additional variables were retained by the model selection process: political affiliation, age, and children at home. The model results for IPR showed that those who identify as "Independent or No Affiliation" were significantly less likely to accept than those identifying as "Democrat." These results generally align with findings by Millan et al. (2015), although the results of other studies examining similar topics have been mixed on the impact, if any, that older age has on acceptance of reuse (Dolnicar et al. 2011; Garcia-Cuerva et al. 2016; Millan et al. 2015; Po et al. 2003).

Table 2. Explanatory variables of two fictional respondent cases and predicted probabilities of each case being unwilling, neutral, or willing to accept DPR and IPR

		Variable or class of willingness	Case 1	Case 2
Demographic Explanatory variables		Gender	Male	Female
		Age	40	27
		Long-term New Mexico resident	Yes	No
		Education level	College degree	Some college
		Political affiliation	Democrat	Republican
		Spanish/Hispanic/ Latino ethnicity	Yes	No
		Children at home	Yes	No
Predicted probabilities	DPR	Unwilling	0.15	**0.40**
		Neutral	0.27	0.24
		Willing	**0.58**	0.36
	IPR	Unwilling	0.14	0.27
		Neutral	0.20	0.27
		Willing	**0.66**	**0.46**

Note: Bold = most likely outcomes for each case.

In the present study's model, both increased age and having children at home had a negative impact on an individual's willingness to accept, in line with findings by Millan et al. (2015). Although there is no strong evidence for the statistical significance of these variables, the model selection criterion (AIC) retained them in the IPR model for their predictive capabilities. For all variables included in the final models, although p-values can be a useful tool for providing evidence that a variable may affect willingness to accept, they say nothing about the strength of the effect, and a small (or large) p-value does not guarantee the presence (or absence) of a relationship (Amrhein et al. 2019; Wasserstein et al. 2019).

For illustrative purposes, the behavior of the model for two fictional Albuquerque residents is demonstrated. The demographic features of these fictional residents were chosen to represent two demographic groups with opposing tendencies for acceptance, with each group being substantially represented in the sample. The explanatory demographic variables of these two fictional cases are given in Table 2, along with the predicted probability that each case will fall into each class of willingness to accept DPR and IPR. The most likely outcomes for each case are bolded.

By plugging the coefficients for the applicable explanatory variables into the ordered logistic regression models, the predictions for willingness to accept DPR and IPR were obtained. In each case for IPR, it is predicted that these subjects would be willing to accept, although the probability of willingness is lower for Case 2. For DPR, the difference between cases is more dramatic. In Case 1, it was predicted that the subject would be willing to accept DPR, but the Case 2 subject would most likely be unwilling to accept. An alternative interpretation is to view these results in terms of groups of respondents. In a group of 100 respondents with the same demographic information depicted in Case 1, one would expect 15 of them to be unwilling, 27 to be neutral, and 58 to be willing to accept DPR. For 100 respondents with the same demographic information depicted in Case 2, one would expect 40, 24, and 36 to be unwilling, neutral, and willing to accept DPR, respectively.

The IPR model contains several variables in addition to those retained by the DPR model, so there are few actual survey respondents with whom to compare these results. However, the model for DPR uses fewer explanatory variables; there are 26 actual survey respondents with the exact same set of demographic data as in

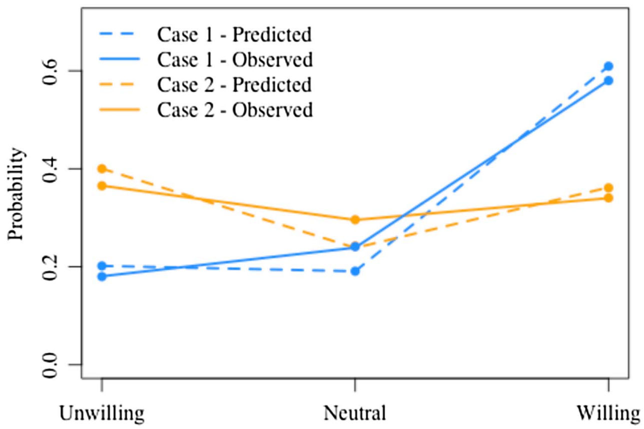

Fig. 2. Comparison of predicted and observed probabilities for two fictional cases regarding willingness to accept DPR.

Case 1 and 62 actual respondents that match Case 2. For DPR, this makes it possible to compare the predicted probabilities with a set of observed probabilities, and this comparison is made in Fig. 2. These respondents of interest (the 26 matching Case 1 and 62 matching Case 2) were held out of the data set, and parameters were estimated again in order to avoid overfitting to these respondents. This leads to a slight difference in the probabilities shown in Fig. 2 compared with what is reported in Table 2.

Fig. 2 illustrates that in both cases, the model is accurately capturing the approximate probability of a respondent falling into a particular category. As discussed in the "Methods" section, the model is fairly accurate when predicting probability of acceptance for groups of individuals.

Explaining Model Results with Trust and Knowledge Data

With ordered logistic regression models, the authors have attempted to determine potential demographic factors that predict the probability of a respondent's willingness to accept potable reuse. The results of these models suggest that several demographic variables may be useful in predicting whether a person is likely to accept potable reuse. It was decided to use only demographic data in the models for purposes of predicting probabilities for groups of people based on demographics. However, previous studies have suggested that a number of nondemographic factors may help to explain a lack of acceptance, such as distrust of various entities and lack of knowledge or awareness of water-related issues (Dolnicar et al. 2011; Macpherson and Snyder 2013; Nellor and Millan 2010; Po et al. 2005). The survey collected information on trust, knowledge, and awareness of water-related issues, and these data were cross-examined with the common explanatory demographic variables retained by the DPR and IPR models to determine if there were significant relationships that may be useful in explaining why some groups were less likely to accept potable reuse.

Chi-square tests of independence were used to examine the relationships among the less accepting demographic groups (i.e., females, those of Spanish, Hispanic, or Latino ethnicity, those with lower levels of education, and non-long-term New Mexico residents) and (1) their level of trust in three entities (local water agency, state/federal regulators, and elected local officials), (2) their prior awareness of potable water reuse, and (3) their knowledge of water scarcity in the region. The results are presented in Tables 3 and 4, which also presents the total number of survey respondents who answered each question, as well as the breakdown of

Table 3. Results of χ^2 analyses showing relationships between demographic variables and level of trust in various entities

	Level of trust in various entities																	
	Local water agency (ABCWUA)						State and federal regulators						Elected local officials					
Demographic variables	n^a	Distrust (%)	Neutral (%)	Trust (%)	df	$p <$	n	Distrust (%)	Neutral (%)	Trust (%)	df	$p <$	n	Distrust (%)	Neutral (%)	Trust (%)	df	$p <$
Total sample	1,565	19.8	25.2	55	—	—	1,667	30.9	22.4	46.7	—	—	1,686	55.8	26.5	17.8	—	—
Gender	1,529	—	—	—	2	NS	1,629	—	—	—	2	NS	1,645	—	—	—	2	NS
Male	729	19.3	23.2	57.5	—	—	765	31.5	22.9	45.6	—	—	772	55.4	26	18.5	—	—
Female	800	20.1	26.8	53.1	—	—	864	30	22.5	47.6	—	—	873	55.7	27	17.3	—	—
Ethnicity (Spanish/Hispanic/Latino)	1,507	—	—	—	2	0.05	1,601	—	—	—	2	0.01	1,616	—	—	—	2	NS
Yes	494	17.6	29.4	53	—	—	517	27.7	27.3	45.1	—	—	525	54.1	29	17	—	—
No	1,013	20.2	23.1	56.7	—	—	1,084	32	20.3	47.7	—	—	1,091	56.3	25.4	18.3	—	—
Education level	1,527	—	—	—	6	0.05	1,626	—	—	—	6	0.001	1,642	—	—	—	6	NS
High school degree or less	195	20.5	28.2	51.3	—	—	205	31.2	27.3	41.5	—	—	213	50.7	28.6	20.7	—	—
Some college	495	22	27.1	50.9	—	—	527	34.7	25.4	39.8	—	—	530	57	27.2	15.8	—	—
College degree	380	21.1	22.1	56.8	—	—	406	29.6	21.4	49	—	—	411	59.1	26	14.8	—	—
Advanced degree	457	15.5	23.4	61.1	—	—	488	27.3	17.8	54.9	—	—	488	52.9	25.2	21.9	—	—
Long-term New Mexico resident	1,534	—	—	—	2	NS	1,634	—	—	—	2	NS	1,651	—	—	—	2	NS
Yes	1,090	19.6	25	55.3	—	—	1,154	30	23.3	46.7	—	—	1,170	55.9	25.8	18.3	—	—
No	444	20	24.8	55.2	—	—	480	32.7	20.6	46.7	—	—	481	55.1	28.1	16.8	—	—

Notes: NS = not statistically significant ($\alpha = 0.05$), and df = degrees of freedom.
[a]No answer (NA) responses omitted from frequencies and percentages included in table.

Table 4. Results of χ^2 analyses showing relationships between demographics and knowledge/awareness variables

	Knowledge and awareness										
	Prior awareness of potable reuse					Water is scarce resource					
Demographic variables	n^a	Yes (%)	No (%)	df	$p <$	n	Yes (%)	No (%)	I don't know (%)	df	$p <$
Total sample	1,801	69.7	30.3	—	—	1,800	82.6	10.6	6.8	—	—
Gender	1,748	—	—	1	0.001	1,745	—	—	—	2	0.01
Male	820	77.3	22.7	—	—	818	83.5	11.6	4.9	—	—
Female	928	63.3	36.7	—	—	927	82.2	9.5	8.3	—	—
Ethnicity (Spanish/Hispanic/Latino)	1,717	—	—	1	0.001	1,714	—	—	—	2	0.001
Yes	583	59.0	41.0	—	—	582	75.1	15.3	9.6	—	—
No	1,134	75.6	24.4	—	—	1,132	87.2	7.8	5.0	—	—
Education level	1,747	—	—	3	0.001	1,744	—	—	—	6	0.001
High school or less	237	58.2	41.8	—	—	239	64.0	21.3	14.6	—	—
Some college	574	60.6	39.4	—	—	572	80.2	11.2	8.6	—	—
College degree	433	76.4	23.6	—	—	433	86.8	8.8	4.4	—	—
Advanced degree	503	79.9	20.1	—	—	500	91.6	5.8	2.6	—	—
Long-term New Mexico resident	1,757	—	—	1	0.05	—	—	—	—	2	0.01
Yes	1,254	68.2	31.8	—	—	1,251	81.0	12.0	7.0	—	—
No	503	74.0	26.0	—	—	503	86.5	7.2	6.4	—	—

Note: df = degrees of freedom.
[a]No answer (NA) responses omitted from frequencies and percentages included in table.

Table 5. P-values for relationships tested using chi-square tests of independence

Variable	Trust in local water agency	Trust in state/federal regulators	Trust in elected local officials	Prior awareness of potable reuse	Knowledge of water scarcity
Gender	0.186	0.715	0.778	<0.001	0.009
Ethnicity	0.028	0.006	0.304	<0.001	<0.001
Education level	0.026	<0.001	0.059	<0.001	<0.001
Long-term New Mexico resident	0.981	0.386	0.578	0.017	0.009

respondents in each demographic category. Table 5 provides a summary of p-values for the chi-square tests of independence reported in Tables 3 and 4. A total of 20 chi-square tests were conducted, and thus all p-values reported for these analyses should be interpreted through the lens of multiple testing, using a Bonferroni adjustment or a similar correction (Bender and Lange 2001).

The results of the chi-square tests of independence show evidence of a relationship between trust in the local water agency and Spanish/Hispanic/Latino ethnicity ($n = 1\,507$, $p = 0.028$). By comparing the level of trust in the local water agency between these ethnicities and other respondents (Table 3), one can see that respondents of Spanish/Hispanic/Latino ethnicity expressed slightly lower levels of trust in the local water agency than those who did not identify with these ethnicities (53% versus almost 57%, respectively), and had a higher percentage of respondents falling into the "Neutral" category of DPR acceptance compared with those who did not identify with these ethnicities (29% versus 23%, respectively). A similar result was also seen in Spanish/Hispanic/Latino ethnicity respondents' trust of state and federal regulators compared with trust levels of those not identifying with these ethnicities (Table 3).

Evidence of a relationship was found between trust in the local water agency and education level ($n = 1\,527$, $p = 0.026$). Fig. S4, a plot showing respondents' trust in the local water agency by education level, indicates that trust in the water agency increases with education level, with about 51% of respondents in the lowest education levels indicating that they trusted the local water agency compared with 61% of those with advanced degrees. A very similar trend was seen with education and trust in state and federal regulators (Table 3). These findings related to trust and education could partially explain why respondents from the bottom two education levels may be less likely to accept both types of potable reuse.

There do not appear to be any significant differences or biases in trust in the ABCWUA based on gender or whether or not the respondent is a long-term New Mexico resident. Similar results were obtained for the gender and long-term resident variables and their relation to level of trust in state and federal regulators. The chi-square analyses also revealed that trust in elected local officials was uniformly low across the demographic variables tested, with nearly 56% of the entire sample distrusting these officials. Thus, it does not appear that lack of trust in elected local officials explains the variation in acceptance for the demographic variables tested.

The chi-square analyses also examined differences in prior awareness of reuse and knowledge of water scarcity among demographic groups. The results presented in Table 4 and summarized in Table 5 indicate evidence of relationships between these topics and all demographic variables tested, with the largest differences in knowledge of water scarcity and prior awareness of potable reuse associated with ethnicity (12% difference between yes and no) and education level (23%–28% difference between groups). For example, about 87% of non-Spanish/Hispanic/Latino respondents believed that water was scarce, compared with only 75% of respondents who identified with these ethnicities ($n = 1\,714$, $p < 0.001$). An even more dramatic trend appeared with education level: 64% of those in the lowest education level believed that water was scarce, compared with 87% and 92% in the top two education levels ($n = 1\,744$, $p < 0.001$). Similar trends for ethnicity and education appeared when investigating prior awareness of potable reuse.

As for gender, female respondents stated lower levels of awareness of potable reuse than their male counterparts, similar to results reported by Millan et al. (2015). Regarding knowledge of scarcity, the most significant gender gap is seen in the "I don't know" category. These differences in awareness and knowledge may be at least partially explained by gender bias in response because research has suggested that women may be less likely to confidently assert knowledge on a subject than men (Miller and Buys 2008).

Finally, relationships were found between the knowledge and awareness variables and whether or not a respondent was a long-term New Mexico resident. It was hypothesized that respondents who had lived in New Mexico for the majority of their lives would be more aware of water scarcity and water-related issues. However, it was found that only 81% of long-term New Mexico residents believed that water was scarce in Albuquerque, compared with nearly 87% of non-long-term residents. Fisher's exact test indicates that this 6% difference is statistically significant, providing evidence that New Mexico natives are actually less aware of water scarcity ($n = 1\,754$, $p = 0.009$). Given this somewhat surprising result, further analyses could be done to determine if the long-term New Mexico residents have higher proportions of groups who are less likely to know about water scarcity (e.g., lower education levels or Spanish/Hispanic/Latino ethnicity) compared with the survey sample as a whole. Overall, the chi-square results suggest that differences in acceptance of reuse between demographic groups can be partially explained by lack of trust in various entities, lower prior awareness of reuse, and lack of knowledge of water scarcity.

Conclusions and Future Research

This paper has presented findings from the first large-scale survey on public attitudes toward potable water reuse in an arid inland US community, and it fills knowledge gaps regarding the demographic and contextual factors that influence acceptance in an arid inland context. As compared with previous studies, it was found that fewer demographic variables were important toward understanding willingness to accept potable reuse, perhaps due to the relatively high degree of awareness of water scarcity. Furthermore, the results indicated remarkably less aversion toward potable reuse. Different from previous research on the factors influencing acceptance of potable reuse, this study also modeled the predictive power of numerous demographic variables on acceptance of two potable reuse scenarios, and then used the results of the model to further investigate contextual reasons (e.g., lack of trust in certain entities) why certain groups might not accept potable reuse. This approach toward creation of inclusive public dialogue and design of tailored education and outreach programming is a new contribution to the literature related to potable water reuse.

Water planners in other arid inland areas can use these findings to better understand the feasibility of potable reuse in their communities. Due to the influence of context (e.g., climate, location, history of water scarcity, and public trust in institutions) on acceptance of potable water reuse, this study's data alone may not be sufficient for planning in other locations, depending on how similar the population of interest is to this study's sample. However, the authors have demonstrated that demographic data can be used to predict the probability of respondents' willingness to accept potable water reuse, and water utilities or other entities could conduct a survey similar to this one and use the presented model to predict acceptance of potable reuse in their communities.

For the ABCWUA and other communities applying the presented approach, the findings may be useful in building trust with targeted segments of the population and designing focused outreach and education programs that are tailored to the various segments of a diverse population. Distrust in the water utility among specific segments of the population could be remedied through meaningful dialogue with those demographic groups. Because distrust in the water utility and lack of water knowledge were associated with lower education levels, the ABCWUA and possibly other utilities should consider supporting ongoing water education programing for young populations (i.e., elementary and junior high school levels).

Regarding future research, Geographic Information System (GIS) software and spatial statistics can be used to more specifically identify areas of a community that may need attention on certain water-related topics. For example, one could identify geographic areas within the ABCWUA service area with hotspots of distrust in the water utility, lack of belief in water scarcity, and misperceptions about climate change or water resources. Such an approach has the potential to be powerful and efficient in building relationships and bringing needed educational information to those who need it.

Data Availability Statement

The data set discussed in this paper has been published, along with instructions for interpretation and use, to aid in further research on water scarcity and climate change-related topics in arid inland areas (Distler and Scruggs 2020b).

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Supplemental Data

Figs. S1–S4 are available online in the ASCE Library (www.ascelibrary.org).

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