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Research paper

Cape Town residents' willingness to pay for a secure and 'green' water supply

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The City of Cape Town experienced a serious drought between 2016 and 2018 which led to severe water shortages and concerns for the environment. This study took advantage of a period of unprecedented levels of awareness about water security in order to investigate households' willingness to pay (WTP) for reliable water supply and their WTP to avoid environmental damages in securing this supply. Increasing the supply of water from dams and groundwater will ultimately impact on aquatic ecosystems, but alternatives are more expensive. We surveyed 248 households from 105 suburbs and used contingent valuation methods to investigate WTP for both secure and less damaging or 'greener' ways of supplying water. Depending on income level, households were willing to pay 63–127% more for their normal levels of consumption in order to have security of supply, and a further 35–68% more to ensure its environmental sustainability. Based on the relationship between WTP for 7 income categories, the overall WTP for secure water supply under non-drought conditions amounted to some 2.8 billion ZAR/year, which is about 90% higher than pre-drought revenues. Aggregate WTP for securing this supply using options that ensured the protection of the region's rivers and estuaries was 3.3 billion ZAR. These results have an important bearing on water investment and pricing decisions over the longer term.

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INTRODUCTION

Securing adequate water supply is one of the most pressing challenges in the global sustainable development agenda and is particularly important for rapidly growing cities in water-scarce regions of the developing world (UNDP, 2016; Gurría, 2017). Meeting growing demands usually comes at increasing marginal cost, both in terms of water supply infrastructure required and the environment.

South Africa is a water-stressed country in which most surface water resources are already fully utilised or overdrawn (Dallas and Rivers-Moore, 2014; DWS, 2021). With population growth and the increasing probability of drought conditions in the Western Cape under climate change, higher levels of investment in water infrastructure will be required to maintain acceptable levels of assurance of supply for residents of Cape Town. Given that lowest-cost options are chosen first, this is inevitably accompanied by rising costs. If lowest-cost options such as dams are used to their maximum, this will lead to the degradation of downstream aquatic ecosystems (Petts, 1996; SWH, 2009; DWA, 2013) to a minimum acceptable threshold which is a state of poor health (40% of natural). Alternatively, costlier alternative sources such as water recycling or desalination could be used in order to maintain both assurance of supply and higher environmental flows if society desires at least some aquatic ecosystems to be maintained in good health. Government authorities are therefore faced with the decision of how much to invest in securing water supply, taking environment into account, as well as how to price water in order to achieve sustainable use at the household level. This requires some knowledge of societal preferences and potential welfare outcomes.

Cape Town already uses a stepped pricing system which capitalises on wealthier households' higher WTP for water and allows for the supply of free water to the poorest households. However, price levels have been relatively low, and have not been effectively used for demand management, now one of the priorities of the National Water Resource Strategy (DWS, 2021). Due to a lack of adequate forward planning and the worst drought in recorded history, Cape Town experienced unprecedented water shortages, resulting in ongoing water restrictions that started in January 2016 with implementation of Level 2 restrictions. By the time of this study in 2017, restrictions were at Level 3, and residents were asked to use less than 100 litres per person per day. Subsequent to this, further restrictions were imposed up to Level 6, emergency plans were announced and there was an awareness campaign to avoid a 'day zero' in which water supplies would be reduced to communal taps. Meanwhile, the Department of Water and Sanitation has to consider the amount of water to be allocated to the 'Ecological Reserve' in the city's water supply catchments through the Classification Process (Dollar et al., 2010). This process entails consideration of both the costs (reduced water yield) and benefits of increasing the Reserve from the minimum legal requirement. The benefits include better capacity for the supply of aquatic ecosystem cultural services. Many of the benefits have public-good characteristics, making them difficult to value. This includes the non-use value (or 'existence value') of maintaining the health and biodiversity of aquatic ecosystems.

The literature on WTP for improved water services has focused mainly on water quality in developing country contexts (Vásquez and Espaillat, 2016; Jiang and Rohendi, 2018; Makwinja et al., 2019; Ahmed et al., 2022; Bui et al., 2022). Studies in other arid regions have shown that urban consumers are willing to pay a higher price to avoid water restrictions, such as in Texas (Griffin and Mjelde, 2001), California (Koss and Khawaja, 2001) and Australia (Gordon et al., 2001; Cooper et al., 2019; Wilson et al., 2021). There are also numerous studies that suggest that urban residents are willing to pay to maintain the health of their urban rivers (Loomis et al., 2000; Holmes et al., 2004; Shang et al., 2012; Morrison et al., 2016), and some that have explored WTP for catchment conservation in the interests of improving water quality (Xiong et al., 2018), water quantity (Balana et al., 2013) or reducing flood risk (Glenk and Fischer, 2010). However, few studies have considered how consumers feel about the environmental impact of meeting their water demands or their WTP for less damaging or 'greener' ways of supplying water.

Most studies that investigate WTP for water services use the contingent valuation method (Hao et al., 2023), although there are other useful methods, such as averting expenditure methods (Orgill-Meyer et al., 2018). In this study, we apply the payment card contingent valuation method to estimate Capetonians' WTP for both a secure water supply and for 'green' water supply over the longer term, the latter requiring the earlier move to more expensive alternatives in order to avoid overstretching surface and groundwater resources to the detriment of the environment. The drought presented a unique opportunity, in that it allowed us to separate these two issues because of the unprecedented high level of public awareness around water supply, prices and household use.

DATA AND METHODS

Data collection

Capetonians' WTP for secure and for green water supply was estimated using the contingent valuation method, which is a survey-based method. Our research targeted all households paying for municipal water supply to their homes in Cape Town.

A household questionnaire was designed in 2 stages. After the initial design, the questionnaire was tested on 14 respondents before being finalised. Face-to-face interviews were carried out by trained enumerators with respondents randomly selected from queues outside the 3 main offices of the Department of Home Affairs (DHA; Wynberg, Bellville and City Centre) during May 2017. Willing participants were only interviewed if they had lived or intended to live in Cape Town for more than a year and they were a decision maker in their household.

DHA locations are visited by a broad cross-section of society because of the requirement to apply for official documentation in person, providing an opportunity for convenience sampling that avoids the known biases towards lower income groups associated with in-situ household surveys in South Africa. Nevertheless, it was anticipated that the sample could be slightly biased towards higher income groups, and for this reason, we used household income as an important factor in the analysis.

Questionnaire structure

The first section covered the respondent's suburb, household size, and property characteristics, and whether they were aware of the drought and water shortages. They were told that the city was looking into options to help secure water supplies into the longer term.

Respondents were then asked to indicate how much they paid monthly for water before the drought, and how much they paid for electricity. They were asked if they thought the price of water was 'appropriate', 'too low' or 'too high', and what would be a reasonable amount to pay for the water they normally used if this would increase security and avoid restrictions. The rationale for these questions was to enhance consequentiality by encouraging respondents to display sensible attitudes towards the hypothetical scenario and to check for consistency in responses. Respondents were then told that improving security of supply in the cheapest way might involve putting pressure on aquatic ecosystems and risk losing a third of aquatic biodiversity in the region, and that this could be avoided by investing in more expensive sources like recycling and desalination.

In the next section, respondents were asked how familiar they were with rivers and estuaries in the region, and whether they would prefer to keep prices low and accept that these would be impacted or accept higher water prices to avoid these impacts. Those choosing the latter were asked to recall their stated WTP for secure water and indicate how much more they would be willing to add. Finally, data were collected on education, income, race and age.

Elicitation of willingness to pay

WTP was elicited using a payment card approach, in which respondents chose their maximum WTP from a list of options (Mitchell and Carson, 1981). This reduces starting point and hypothetical bias and other problems associated with open-ended and iterative bidding methods (Haefele et al., 2019; Aseres and Sira, 2020; Xu et al., 2020). While there are concerns about this method being upwardly biased compared with dichotomous choice elicitation (Rowe et al., 1996; Cameron et al., 2002; Covey et al., 2007), several studies have found similar or lower results for payment cards when the two methods have been tested together (Ready and Buzby, 1996; Welsh and Poe, 1998; Reaves et al., 1999; Ready et al., 2001; Wang and Whittington, 2005; Xu et al., 2020). Ready et al. (2001) found that when respondents were asked to be 95% sure that they would in fact pay their stated values, they lowered their dichotomous choice amount but did not change their payment card amount. In uncovering the WTP for urban green space conservation, Xu et al. (2020) found that the payment card approach yielded more conservative and intuitive results concerning respondents' preferred values when compared to open-ended and dichotomous bidding approaches.

While the payment card approach has its strengths, a key concern is that it does not generally meet the conditions for incentive compatibility (Zawojska and Czajkowski, 2017). An incentive-compatible survey mechanism incentivises respondents to truthfully reveal their maximum WTP (Kabaya, 2021), which according to Carson and Groves (2007), is a condition that can only be truly satisfied with the use of a referendum-style binary-choice question. Although, more recently, theoretical conditions for open-ended and payment card questions have demonstrated incentive compatibility (Vossler and Holladay, 2018; Gordillo et al., 2019). The second condition for truthful preference revelation is consequentiality (Carson and Groves, 2007; Zawojska and Czajkowski, 2017). A survey is considered consequential when (i) the respondent believes their choice can influence actions for future supply of the public good, (ii) respondents care about the outcomes of the survey, and (iii) respondents believe that if the project/policy is implemented payment will be enforced (Zawojska and Czajkowski, 2017; Kabaya, 2021). While it is recommended practice to design a survey in an incentive-compatible manner, the number of studies that meet the incentive compatibility conditions remains limited (Zawojska and Czajkowski, 2017). However, the CV method (including payment cards) has a long history of use in major policy areas (Chatterjee et al., 2017). Thus, to enhance perceived consequentiality and reduce the potential for strategic and hypothetical bias, our survey used a compelled payment vehicle in the form of a monthly utility bill and used statements that suggested implicitly that our research could influence water policy.

We asked respondents to select the amount that best corresponded to their maximum WTP from a list of amounts ordered from lowest to highest, as is commonly done (Covey et al., 2007; Haefele et al., 2019; Table 1).

The money amounts on the payment card were selected based on responses during the pre-testing phase and actual water bill data for the City of Cape Town. With this approach, the true WTP of respondents is assumed to be located above the chosen value and below the next highest one (Haefele et al., 2019). Unbounded upper responses accounted for less than 2% of our survey respondents in the first WTP question, but 13% in the second WTP question. It is possible to use a naïve ordinary least squares procedure employing interval midpoints as proxies for the true dependent variable, or an efficient maximum likelihood (ML) procedure which explicitly accommodates the intervals and is less likely to be biased (Cameron and Huppert, 1989; Greene, 2012). Alternatively, the chosen amounts can be treated as a best estimate (i.e. similar to a Lower Turnbull estimate). For this analysis the WTP estimates were inferred directly from the data using an efficient maximum likelihood estimation (Cameron and Huppert, 1989; Belyaev and Kriström, 2010; Cooper et al., 2019). The basis underlying this approach is that circling R100 (100 ZAR) on the payment card, for example, reveals that 100 ZAR ≤ WTP_i < 200 ZAR and that the contribution to the overall likelihood function is the probability that WTP_i lies between 100 and 200 ZAR, conditional on a vector of explanatory variables and a set of unobservable factors captured by an error term (Cameron and Huppert, 1989; Leggett et al., 2003).

Therefore the log-linear WTP function for the i_{th} respondent can be written as:

$$\text{Ln(WTP)}_i = X_i\beta + \varepsilon_i \quad (1)$$

where Ln(WTP)_i is the underlying natural logarithm of WTP for secure or green water supply and i denotes the individual respondent; X_i denotes a vector of respondent and household characteristics; β is a vector of coefficients to be estimated; and ε_i is the stochastic error term. Effectively, Eq. 1 describes a WTP-survival function based on the Weibull distribution (Itaoka et al., 2005; Zhou et al., 2012). The log-likelihood function of the data can be defined as:

$$\text{Log } L = \sum_{i-1}^{n} \log\left(F((\text{WTP}^H_i - X_i\beta)/\sigma)) - F((\text{WTP}^L_i - X_i\beta)/\sigma)\right) \quad (2)$$

where F is the Type I extreme value distribution with scale σ, WTP^H_i and WTP^L_i are upper and lower bounds for WTP, X is a vector of respondent and household characteristics with β as the corresponding coefficients and σ is the scale parameter of ε, as well as the reciprocal of the shape parameter of the Weibull distribution describing WTP. The Weibull distribution is versatile in that it can take on the characteristics of other distribution types based on the value of this shape parameter (σ). The advantage of using a Weibull parametric distribution is that the variates are defined on the positive semi-axis and have a flexible shape parameter, resulting in the Weibull having a higher log-likelihood and narrower disparity between medians and means compared to logistic, log-normal and normal distributions (Alberini et al., 2005; Itaoka et al., 2005).

We calculated WTP estimates based on the Weibull and mixed Weibull families of distribution and estimate nonparametric WTP estimates based on the empirical survival function. The mixed Weibull and nonparametric distributions differ from the Weibull model in that they are used to model data that may not fit the Weibull probability plot (mixed multimodal) or data that are distribution-free (nonparametric). Nonparametric estimates are generally less efficient than parametric estimates (Hutchinson et al., 2001) and are simplistic in that they do not have any distributional assumptions for the unobserved component of preferences and are unable to consider the effects of independent variables on WTP, i.e., are unsuitable for covariate analysis (Hutchinson et al., 2001; Carandang et al., 2008; Truong, 2021). However, they are flexible and unlike parametric models are free from distributional assumptions (Hutchinson et al., 2001).

The R programming language (Version 4.1.3) was used for all data analyses (Zhou et al., 2012; R Core Team, 2023). A total of 32 questionnaires with missing data or extreme values associated with stated electricity and water bills were excluded from the analysis. This resulted in a sample size of 248 households. Mean WTP was estimated for 7 income categories corresponding to groupings in the 2011 Census (Stats SA, 2012). Aggregate WTP for a secure and 'green' water supply was determined by multiplying the mean WTP per income category by the number of households in Cape Town within each of these income groups, considering the proportion of households choosing to accept higher prices.

Validation

The Weibull models were also used to explore the association between WTP and socioeconomic factors (Table 2). The first model explored the association between WTP for a secure water supply and household income, household size, age, race, education and whether the household had a garden, pool or borehole. To explore the probability of respondents being willing to accept higher water prices to reduce further impacts on rivers and estuaries, a binomial generalised linear model (GLM) was used. Then, for the respondents that were willing to accept higher prices, the second Weibull model explored the additional WTP for this 'green' water supply (i.e. higher prices to reduce further impacts on rivers and estuaries) and the same explanatory variables as the first model with the addition of the level of familiarity of the respondent to aquatic ecosystems and whether or not the respondent had a river in their neighbourhood.

The presence of multicollinearity was tested using the variance inflation factor (VIF), which specifies the strength of linear dependencies and identifies how much of the variance of each coefficient is inflated due to collinearity when compared to the independent variables (Yoo et al., 2014). The generally accepted approach is that multicollinearity is an issue when the VIF values are in excess of 5 or 10; however, a more stringent approach is to use a cut-off as low as 3 (Zuur et al., 2010), as we did in this study. For both models, backward stepwise elimination was performed on explanatory variables at the 5% significance level until the minimum adequate model remained. Covariates that are not reported in the Weibull model estimation results were excluded through this process.

Table 1. The payment cards used to elicit WTP. Amounts were denoted in South African Rands (1 USD ~ 13 ZAR in May 2017).

PC 1: WTP for reliable water supply (ZAR/month)							
<99	100–199	200–399	400–499	600–799	800–1 199	1 200–1 999	2 000+
PC 2: WTP to avoid environmental damages in securing supply (additional ZAR/month)							
2	5	10	25	50	100	250	

Table 2. Dependent and explanatory variables used in the Weibull models and binomial GLM for the analysis of WTP to avoid water shortages in the future, and WTP higher prices to reduce further impacts on rivers and estuaries in the south-western Cape

Dependent variables			Description
1. WTP for secure water			The maximum respondents are willing to pay per month for a secure supply of water (ZAR/month)
2. Willingness to accept higher water prices			The probability of respondents willing to accept higher water prices to reduce further impacts on rivers and estuaries (0 or 1)
3. WTP for green water			The additional amount respondents are WTP per month in order to secure the condition of rivers and estuaries (ZAR/month)
Explanatory variables	**Type**	**No. of levels**	**Description**
Household income	Continuous	1	Ln median household income (ZAR)
Household size	Discrete	1	Number of people in household
Age	Categorical	6	Brackets of respondent's ages: 20–29, 30–39, 40–49, 50–59, 60–69, and 70+
Race	Categorical	4	Race of respondent: Black, White, Asian and Coloured
Education	Categorical	6	Level of education: none, primary, secondary, matric, diploma, degree
Garden	Binary	2	Property has a garden (1 = yes, 0 = no)
Pool	Binary	2	Property has a pool (1 = yes, 0 = no)
Borehole	Binary	2	Property has a borehole or well point (1 = yes, 0 = no)
Familiarity	Categorical	4	Familiarity to rivers and estuaries: not familiar, somewhat familiar, familiar and very familiar
River in neighbourhood	Categorical	3	Respondent has river in neighbourhood: yes, no, don't know

Table 3. Demographic characteristics of sample

Income category (ZAR per household per month)	%	Age group	%
0–4 350	13.8	18–29	20.6
4 351–8 700	11.2	30–39	30.8
8 701–17 500	15.6	40–49	25.9
17 500–35 000	22.3	50–59	14.2
35 000–70 000	19.2	60–69	6.9
70 000–140 000	7.6	>70	1.6
140 000+	10.3		
Education level	**%**	**Race**	**%**
None	1.2	Black	21.8
Primary	3.3	Coloured	39.3
Secondary	16.5	White	37.9
Matric	28.0	Asian	1.1
Tertiary	51.0		

RESULTS

Sample characteristics

A total of 248 people were interviewed, of whom 55% were female. Most respondents were between the ages of 18 and 49 (Table 3). The respondents came from 105 of Cape Town's 128 suburbs and had a mean household size of 4.1 (± 2.1, range 1–15). There were significant differences in race composition ($X^2 = 0.35$, $p < 0.05$) and in income level ($X^2 = 2.17$, $p < 0.01$) of the sample compared to the Cape Town population (Stats SA, 2012), with a bias towards wealthier and White households and away from poor and Black households. Half of respondents (51%) had a tertiary level qualification, 58% had a garden at home, 23% had a pool and 13% had their own borehole or well-point. The largest difference between observed and expected income categories was seen in the lowest income category where the observed frequency of respondents was significantly lower than expected. However, there was no difference in the composition of households in the survey from the population earning 2 125 ZAR/month or more. We therefore assumed that the lowest income category ranged from this minimum rather than zero. This generates a more conservative overall result.

Drought awareness and WTP for secure water supply

Almost all (97%) of the respondents interviewed were aware that Cape Town was experiencing severe water shortages. Most respondents (71%) knew what their household monthly water bill was and, of those that did, the majority (60%) felt that the price of water was appropriate, 17% felt it was too low, 16% felt it was too high and the rest did not have an opinion. The frequency distribution of raw responses to the first WTP question regarding monthly household payment for a secure water supply shows that the responses were right-skewed, distributed around the modal value of 200 ZAR/month (Fig. 1).

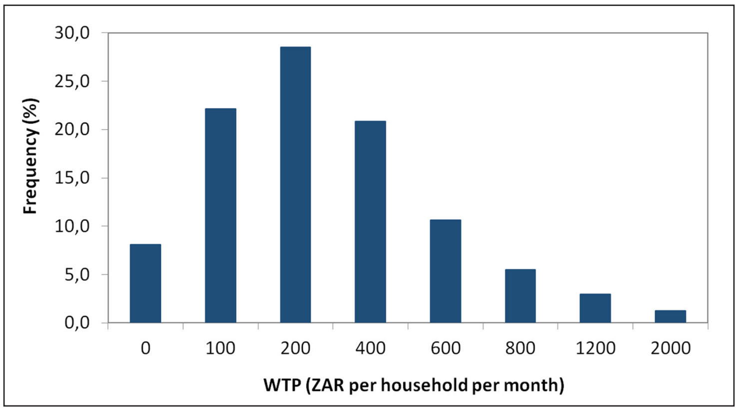

Figure 1. Frequency distribution of the WTP for secure water supply; *n* = 235

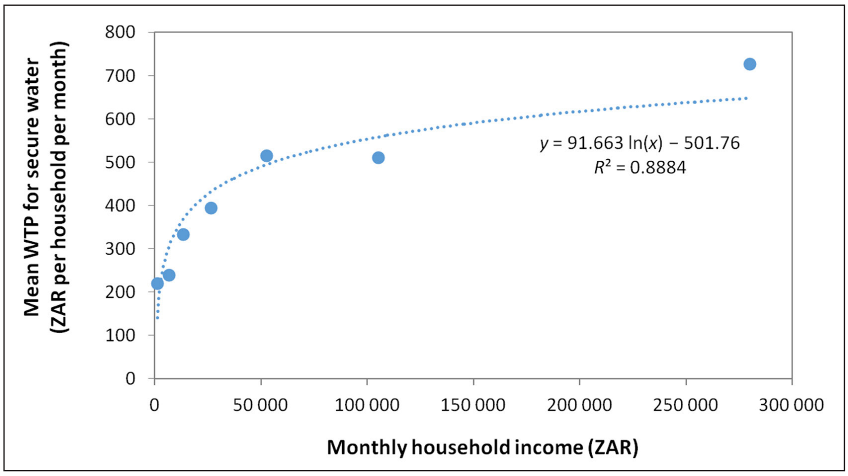

Figure 2. Estimated mean WTP for secure water supply from the Weibull models, plotted against the midpoint of each income category

Table 4. Mean WTP estimates (ZAR per household per month)) from the first Weibull model

	Scale	Shape	Max. likelihood	Mean WTP
Overall model	454.72	1.434	−406.89	413
Income category 1	236.35	1.254	−44.34	220
Income category 2	270.79	2.533	−25.91	240
Income category 3	374.57	1.755	−53.57	334
Income category 4	444.67	1.864	−80.45	395
Income category 5	574.76	1.588	−78.52	516
Income category 6	577.12	1.943	−29.46	512
Income category 7	814.58	1.692	−45.96	727

The outputs from the Weibull and mixed Weibull models were similar, confirming that the data do satisfactorily fit the Weibull probability plot distribution, as was expected. The nonparametric estimate was higher than the other two estimates for all income categories. This result is consistent with the findings of Carandang et al. (2008) and Truong (2021), and is likely an impact of maximum bid amounts and sample size. The outputs from the Weibull model were taken as the most accurate estimate of mean WTP given the frequency distribution of the data and the fit of the Weibull probability plot (Table 4). Based on the Weibull estimates for each of the 7 income categories, mean WTP for secure water supply increased logarithmically with household income (Fig. 2).

Based on the amount that households were paying for water before the start of the drought, this represented an average increase of between 63% and 127% for the same level of consumption (approximately 12.6–25.9 kL/month under the assumption of 6 kL for zero-paying households), in order to have a secure water supply and avoid restrictions. This is conservative given that consumption may have been overestimated due to unknown consumption in the 0–6 kL range. Nevertheless, WTP for secure water supply was considerably above Level 1 (non-drought), higher than Level 2–4 prices, and also exceeded the adjusted Level 1 prices based on the 20% increase announced in May 2018 (Fig. 3).

WTP for a secure supply of water was significantly related to household income level and whether the respondent had a swimming pool (Table 5). Higher-income households were willing to pay significantly more per month for a secure water supply compared to low-income households and respondents with a swimming pool were also willing to pay significantly more per month than households without a pool (Table 5).

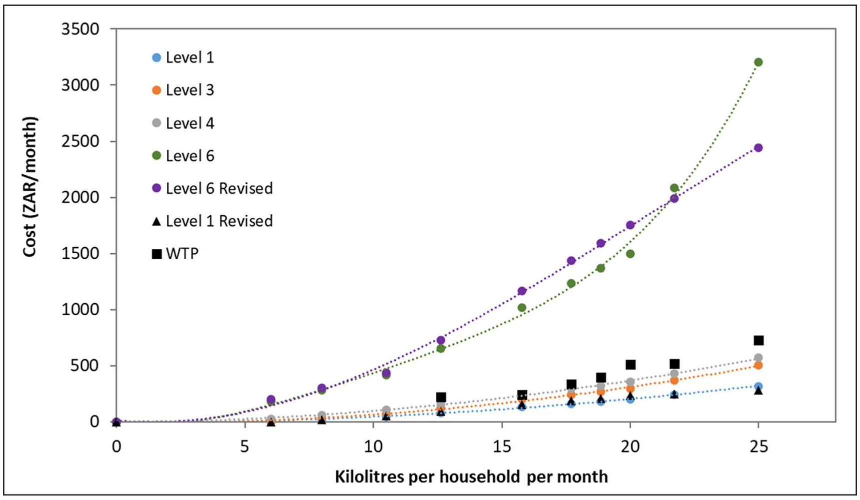

Figure 3. Change in cost of water in relation to household use, based on a stepped pricing structure, for Level 1 (pre-drought), Level 3 (at time of survey), Level 4, Level 6 and the May 2018 revision to Level 6 prices. Level 1 revised is the May 2018 percentage increase applied to Level 1. The graph also shows average household WTP for secure water at the average level of consumption estimated from stated pre-drought water payments, for each income category (1–7).

Table 5. Weibull Model 1 estimation results. Dependent variable is WTP for secure water (ZAR per household per month); ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

Variable	Co-efficient	Std. error	*z*-value	*p* (>|*z*|)
(Intercept)	3.956	0.354	11.19	$<2 \times 10^{-16}$***
Swimming pool (yes)	0.304	0.117	2.60	9.2×10^{-3}**
Ln household income	0.206	0.036	5.70	1.2×10^{-8}***
Log(scale)	−0.476	0.053	−9.03	$<2 \times 10^{-16}$***
Scale		0.621		
Loglik(model)		−1 425.7, $P = 2.7 \times 10^{-15}$***		

WTP to secure river and estuary health

Respondents were largely ignorant of the rivers and estuaries of the south-western Cape, with 34% unfamiliar, 38% somewhat familiar – having noticed some rivers and estuaries, 19% saying they knew some of the systems well and only 9% claiming they were very familiar with several rivers and estuaries. Nevertheless, 72% of respondents said they were willing to accept higher water prices to avoid further impacts on rivers and estuaries, as opposed to keeping prices low and accepting that rivers and estuaries will be impacted. The likelihood of accepting higher prices to have a greener water supply ranged from 40–90% per income category and increased logarithmically with income (%WTP = −0.259 + 0.098 · ln(Income), $R^2 = 0.72$, $p < 0.05$).

Among respondents who were willing to pay more for greener water supply, the frequency distribution of responses regarding their WTP over and above their WTP for secure water supply was distributed around the modal value of 100 ZAR/month, but the distribution was truncated (Fig. 4). Therefore, the WTP estimates from these data could be underestimated.

Based on the percentage of each income category that was willing to pay a premium for greener water, and their estimated mean WTP, the overall mean WTP was estimated per income category, from the Weibull model. This increased logarithmically with household income (Fig. 5). The overall mean WTP for a greener water supply was estimated to be 116 ZAR per household per month.

Figure 6 shows the average monthly amount that households in each income category paid for water before the drought, the average additional amount they were willing to pay for a secure supply (i.e. avoiding water shortages in the future), and the average additional amount they were willing to pay to secure the condition of aquatic ecosystems through use of lower impact water supply technologies. As expected, all amounts increase with income category.

Household size and income explained a significant amount of variation in the probability of respondents being willing to accept higher water prices to reduce further impacts on rivers and estuaries (Table 6). Higher-income households were more likely to accept higher prices than lower-income households and larger households were less likely to accept higher prices compared to smaller households.

Among the households that were willing to pay for green water supply, household income and level of familiarity with rivers and estuaries explained a significant amount of variation in WTP (Table 7). Higher-income households and those that were 'very familiar' with the rivers and estuaries in the region were willing to spend significantly more than other households.

Aggregate WTP

The overall average annual household WTP for secure water supply ranged from 2 640 to 8 725 ZAR per household per income category. The City of Cape Town has just over 980 000 households, of which just under 680 000 earn more than 2 125 ZAR/month (Stats SA, 2012). Based on WTP per income category, the aggregate WTP by the latter households for security of supply at pre-drought levels of use was in the order of 2.8 billion ZAR/year. In addition, the aggregate WTP to secure the health of rivers and estuaries in the south-western Cape was 0.5 billion ZAR/year.

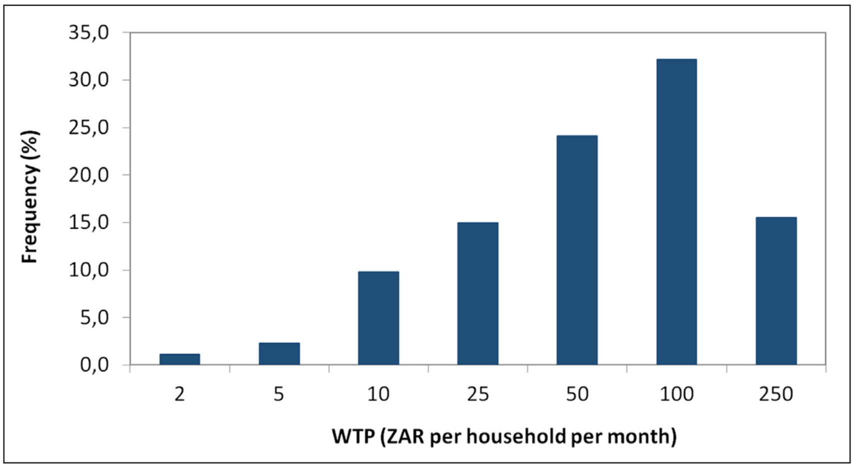

Figure 4. Frequency distribution of the additional WTP for securing the condition of rivers and estuaries by the 74% of respondents with positive WTP; *n* = 174

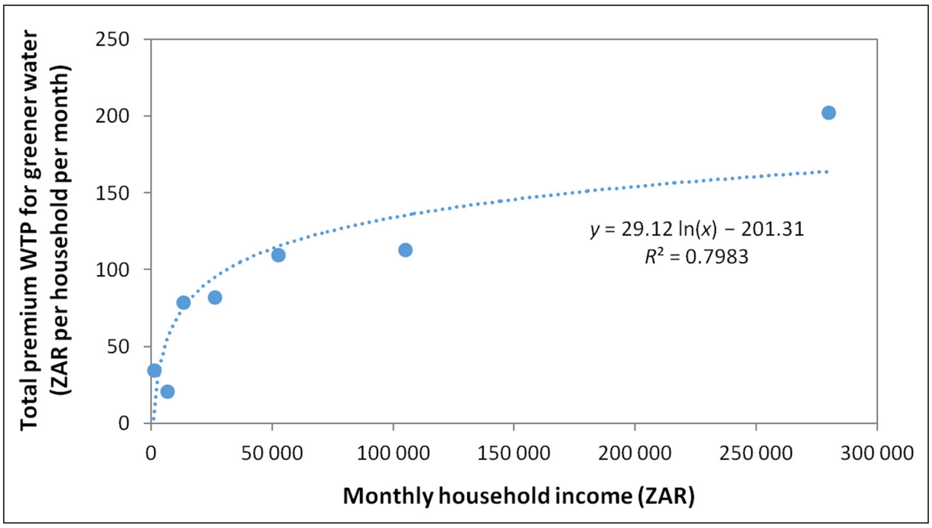

Figure 5. Additional mean WTP to secure the condition of rivers and estuaries per income category

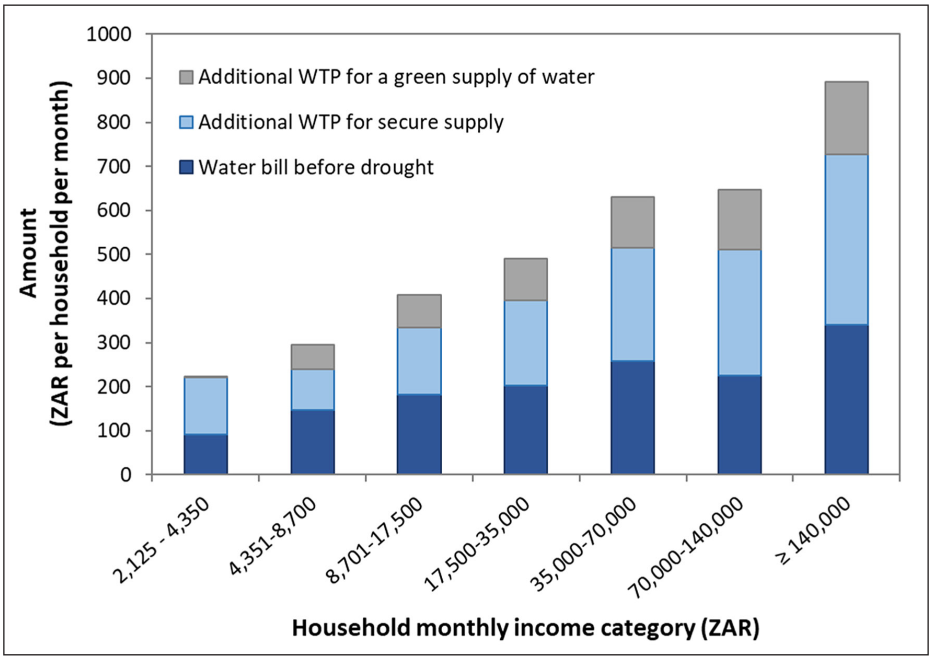

Figure 6. The average monthly water bill households were paying before the start of the drought, average additional WTP for secure supply of water and average additional WTP to secure the condition of rivers and estuaries per household income bracket.

Table 6. GLM (Binomial, link: logit) estimation results. Dependent variable is willingness to accept higher water prices (binomial, 1 or 0); ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

Variable	Co-efficient	Std. error	*t*-value	*p* (>|*t*|)
(Intercept)	−3.74345	1.42033	−2.636	8.40×10^{-3}**
Household size	−0.17444	0.08088	−2.157	3.10×10^{-2}*
Ln Household Income	0.56337	0.13525	4.165	3.11×10^{-5}***
AIC	218.3			

Table 7. Weibull Model 2 estimation results. Dependent variable is WTP for green water (ZAR per household per month); ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$. 'Familiar' serves as the reference category for the rivers and estuaries familiarity indicator.

Variable	Co-efficient	Std. error	*z*-value	*p* (>|*z*|)
(Intercept)	3.497	0.439	7.95	1.8×10^{-15}***
Ln Household Income	0.139	0.039	3.59	3.4×10^{-4}***
Familiar: Not familiar	−0.167	0.161	−1.04	0.297
Familiar: Somewhat familiar	−0.115	0.144	−0.80	0.426
Familiar: Very familiar	0.269	0.208	1.29	1.95×10^{-3}**
Log(scale)	−0.415	0.066	−6.31	2.7×10^{-10}***
Scale		0.661		
Loglik(model)		−889.3; $p = 3.3 \times 10^{-4}$***		

DISCUSSION

This study investigated Capetonian's WTP for secure water supply and also avoiding negative impacts on the health of aquatic ecosystems from excessive water abstraction. This is extremely pertinent, as the increasing likelihood of major droughts could pose a serious threat to the future integrity of aquatic ecosystems in the absence of investment into sustainable alternatives to surface water supply.

Capetonians' WTP for security of supply was significantly above non-drought water prices and even higher than the prices during Level 2–4 restrictions. It also exceeded the Level 1 (non-drought) prices if these were to be subjected to the 20% increase announced in 2018. Aggregated at the city level, this additional amount translated into 2.8 billion ZAR/year, which was 1.4 billion ZAR more than the total amount actually paid by residents at the time (Cook et al., 2021). Furthermore, aggregate WTP would be 3.3 billion ZAR if the supply was secured in ways that would also avoid further risk to rivers and estuaries, such as through catchment restoration, wastewater recycling and desalination. This suggests that capturing consumer surplus, here estimated to be about 1.9 billion ZAR/year, could comfortably provide the funding required for both secure and green (environmentally sustainable) water supply. Of the latter options, the **annual** surplus comfortably exceeds the approximately 370 million ZAR (in total) needed to clear alien invasive plants, which is the top priority based on return on investment (Turpie et al., 2018; TNC, 2019), and also exceeds the 1.5 billion ZAR capital expenditure that the City estimated was needed for diversification of water sources to mitigate water shortages (CCT, 2018). Covering these amounts would therefore potentially only require a fraction of the expressed additional WTP.

While many studies have estimated WTP for secure and clean water supply, relatively few have investigated WTP for water supply that avoids biodiversity loss (Loomis et al., 2000; Ojeda et al., 2008; Shang et al., 2012), and none, to our knowledge, have considered these together. This avoided confounding these two elements, especially in a post-drought situation.

WTP for green water supply was expected to be lower than WTP for secure water supply, since not all users would be aware of or concerned with environmental issues. Indeed, only a small percentage of respondents were familiar with the rivers and estuaries of the region. Nevertheless, after being informed about the potential consequences of drawing on cheaper options (surface water resources), almost three quarters of respondents were willing to accept higher water prices to avoid this. Among these, WTP increased with the respondent's level of familiarity with rivers and estuaries as well as household income. Larger and lower-income households were least likely to accept higher water prices to reduce environmental impacts. In general, both the understanding of environmental issues and WTP for conservation increases with education and income (Urama and Hodge, 2006; Gifford and Nilsson, 2014; Nguyen et al., 2016).

The contingent valuation method is prone to a number of biases. For example, it is important to provide enough information upon which respondents can base decisions, but if respondents are 'sold' the idea of green water supply (e.g. see Loomis et al., 2000), then their WTP would only reflect what might be achieved with awareness raising. Our survey provides very limited information on the risks to rivers and estuaries, but this may have raised the interest of some respondents, contributing to a higher than expected level of support for raising prices to supply green water. Respondents may also provide a more socially acceptable answer than their true response, as they are uncomfortable admitting that they are unable to contribute towards a desirable outcome (Kaminska and Foulsham, 2013). Nevertheless, our results were consistent with the international literature in that WTP for water increased with household income (Gordon et al., 2001; Griffin and Mjelde, 2001; Koss and Khawaja, 2001; Asim and Lohano, 2015; Rananga and Gumbo, 2015), providing important validation.

Of the respondents who had zero or low WTP, many commented that this was as a result of distrust and low confidence in the City of Cape Town and their management of the drought situation. Certain individuals felt that the rates and taxes that they were already paying was not being efficiently spent on service delivery.

Many of these residents stated that they would only be willing to pay higher fees if there was some guarantee that the money was being used to address water supply rather than to supplement city revenues. Indeed, the lack of trust in local government has previously been found to explain the lack of payment for services in South African towns (Fjeldstad, 2004). This suggests that, under the right institutional arrangement, aggregate WTP for secure and greener water supply might be higher than the results reported here.

CONCLUSIONS

Our findings indicate that Capetonian households are not only willing to pay significantly more for their water to have security of supply but are willing to pay even higher amounts to avoid environmental damages in securing this supply. This suggests that domestic water tariffs could be raised in line with the proportionally higher consumer surplus of higher-income households and the increased revenues would be sufficient to address water security using environmentally sustainable approaches. The results also suggest that trust in municipal institutions plays an important role, and that public support for tariff hikes would be significantly improved if water revenues were ringfenced for this purpose.

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AUTHOR CONTRIBUTIONS

Jane Turpie was project leader and responsible for conceptualisation, methodology, funding acquisition and writing. Gwyneth Letley assisted with methodology, data collection, analysis and writing.

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