Journal of Environmental Planning and Management, 2025
https://doi.org/10.1080/09640568.2025.2586549

Urban household uptake of water-sensitive urban design measures in the context of an applied water demand management study

Jacques du Toit*

Department of Town and Regional Planning, University of Pretoria, Pretoria, South Africa

(*Received 26 December 2024; final version received 4 November 2025*)

Water-sensitive urban design (WSUD) requires widespread household participation to achieve resilient urban water systems. Yet, surveys on de facto and intended uptake of WSUD measures are limited in developing countries. This article determines uptake and predictors of rainwater harvesting, permeable paving and greywater reuse systems across different settlement types in the Gauteng city region of South Africa. Data were collected as part of an applied water demand management study, in which uptake was conceptualised as a form of conservation using an integrated model of household water consumption. Current and intended uptake of especially rainwater harvesting was noticeable among water-saving suburban households with tertiary education, but less so among township households. Predictors of conservation intention otherwise explained intended uptake to a limited extent. Three directions for more systematic research were identified to help integrate a growing, but as yet fragmented, body of research on both the nature and facilitation of uptake.

Keywords: water-sensitive urban design; water demand management; rainwater harvesting; permeable paving; greywater reuse systems

1. Introduction

Climate change, rapid urbanisation and infrastructural decline have led to an increasing recognition that cities need to become more water sensitive to mitigate shortages and environmental degradation. The Urban Water Management Transitions Framework by Brown, Keith, and Wong (2009, 850) depicts how cities could evolve toward water sensitivity through stages of increased service delivery. Central to this framework is the notion of a shifting hydro-social contract, where societal expectations of water services expand from basic supply and sanitation toward integrated, adaptive and ecologically oriented urban water management. The end state of a "water-sensitive city" is characterised by multifunctional infrastructure, community involvement, and resilience to climate and urbanisation pressures. In South Africa, the transition toward water sensitivity is complicated by the country's dual urban structure where formal and informal settlements coexist with unequal access to infrastructure, tenure security and municipal

*Email: jacques.dutoit@up.ac.za

support. Fisher-Jeffes, Carden, and Armitage (2017, 7) therefore adapted the Urban Water Management Transitions Framework to the South African context, highlighting how solutions must be tailored to the realities of fragmented urban governance and socio-economic disparity.

A water-sensitive city is one where urban water management is therefore sustainable, resilient and productive for all (Chadfield, Wei, and Lieske 2024). Water-sensitive urban design (WSUD), which covers all aspects of urban water management, aims to create water-sensitive cities by restoring natural water cycles and minimising negative impacts of urban water cycles (Rashetnia *et al*. 2022). WSUD includes the principle of managing stormwater as close as possible to its source (i.e. at site or property level), a principle also known as green infrastructure (Sharma *et al*. 2016; Conway *et al*. 2023), sustainable urban drainage systems in the United Kingdom, or low impact development in New Zealand and North America (Fletcher *et al*. 2015). WSUD measures at site level can include rainwater harvesting and permeable paving to minimise stormwater runoff (Armitage *et al*. 2014), and greywater reuse to minimise wastewater (Pinto and Maheshwari 2010).

Considering that roughly half of land use in South African cities is typically low-density residential (see Figure 1 and the Spatial Development Framework for the City of Johannesburg Metropolitan Municipality 2024), household uptake of WSUD measures can significantly reduce the negative impact of the urban water cycle. This is particularly the case in South Africa where climate change, rapid urbanisation and infrastructural decline have an effect on water quality and security (Carden *et al*. 2018). Yet, suburban households may view stormwater, for example, as a public rather

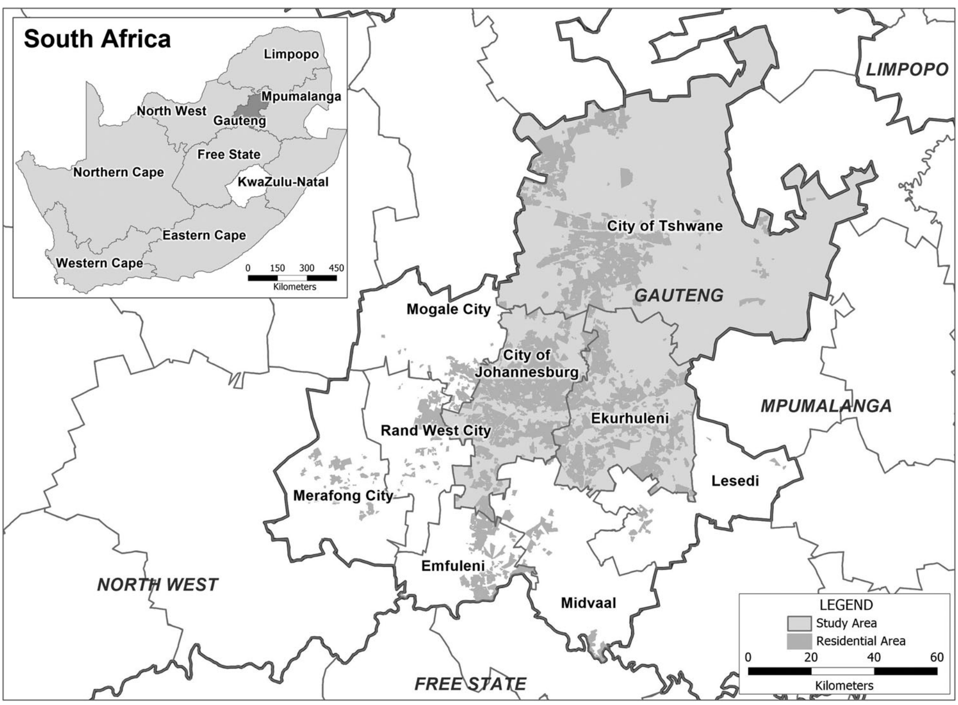

Figure 1. Map of the study area.
Data sources: Municipal Demarcation Board and Statistics South Africa.

than a private issue (Turner, Jarden, and Jefferson 2016). They may, therefore, not adopt WSUD measures as easily as normal water-saving practices. To achieve water-sensitive cities, there should be a better understanding of household uptake of WSUD measures and how to facilitate them. Social acceptance of these measures is essential for their successful planning, design and implementation at site level (Brown *et al*. 2016; Buurman and Padawangi 2018; Cockerill *et al*. 2019; Dean *et al*. 2023).

A substantial body of literature on WSUD focuses on policy, design and the environment (Sharma, Gardner, and Begbie 2019), as well as household uptake (see, e.g. Sharma *et al*. 2016; and the literature reviews in Mankad and Tapsuwan 2011; Venkataramanan *et al*. 2020; Ahmed, Parker, and Drescher 2025). Studies on uptake among urban households focus either on de facto uptake (see, e.g. Cockerill *et al*. 2019) or on intentions or hypothetical scenarios (see, e.g. Schirmer and Dyer 2018; Shin and McCann 2018; Leonard *et al*. 2019; Dean *et al*. 2023). Some studies focus on subsidised or incentivised programmes (see, e.g. Thurston *et al*. 2010; Ando and Freitas 2011; Brown *et al*. 2016; Gao *et al*. 2016; Conway *et al*. 2023) or experimental conditions (see, e.g. Turner, Jarden, and Jefferson 2016). Moreover, the cited studies focus exclusively on developing countries, notably Australia and the United States. Surveys that examine de facto past, present, *and* future intended uptake across the socio-economic spectrum or different settlement types, including the predictors of uptake, are limited, especially in developing countries. Moreover, predictors appear to differ between measures, and are often inconclusive (Ahmed, Parker, and Drescher 2025). The literature also appears fragmented, lacking theoretical and methodological integration across studies or guidance as to how WSUD can be implemented more effectively at site level. Most studies are theoretically and methodologically unique, and do not yet appear to employ a more unifying theory or methodology to study uptake more systematically.

Considering the above, the present study had two research aims; first*, to determine the de facto past, present, and future intended uptake of selected WSUD measures among households in the Gauteng city region of South Africa, as well as the influence of settlement type on uptake*, and second, *to determine the effect of predictors of water conservation intention on intended uptake*. Settlement type plays an important role in South Africa because of historical socio-economic differences between formerly designated "white" suburbs and "black" townships (Carden *et al*. 2018, 9). Moreover, a better understanding of the predictors of uptake might better inform the planning and implementation of WSUD at site level and the assistance of households to adopt WSUD measures. In this study, WSUD measures related to both stormwater and wastewater, and included rainwater harvesting, permeable paving, and greywater reuse systems. Based on the findings, the study provides directions for more systematic research on both the nature and facilitation of uptake.

The findings reported here formed part of an applied water demand management (WDM) study. WDM involves managing the demand for, or consumption of, water for purposes such as protecting the environment and maintaining the security and efficiency of water supply (Kampragou, Lekkas, and Assimacopoulos 2011). WSUD and WDM overlap by definition. WSUD is a way through which some of the objectives of WDM can be integrated into settlement planning and design (Carmon and Shamir 2010; Larson *et al*. 2010; Gober *et al*. 2013; Carden *et al*. 2018). WDM is, however, primarily about municipal water and includes measures for the *efficient* use thereof (Funke *et al*. 2017), whereas WSUD includes measures for water *sensitivity* relating to stormwater and wastewater (Armitage *et al*. 2014; Cockerill *et al*. 2019). Still, WSUD can be studied in the context of WDM if uptake of WSUD measures, such as rainwater harvesting, is seen as a form of conservation that may influence demand (Jorgensen, Graymore, and O'Toole 2009; Sharma *et al*. 2016).

The applied WDM study referred to above was carried out in South Africa by the Council for Scientific and Industrial Research (CSIR). Considering the overlap between WDM and WSUD, the University of Pretoria entered into a formal research collaboration with the CSIR. The CSIR provided logistical support for a household survey, and the University involved students as fieldworkers. Students, in turn, acquired project-based learning and data for their final-year research project. The University was able to include questionnaire items relating to rainwater harvesting, permeable paving and greywater reuse systems, and to analyse the data within a theoretical framework for household water consumption.

2. Theoretical framework

As indicated earlier, uptake of WSUD measures can be studied in the context of WDM if uptake is conceptualised as a form of conservation. The present study therefore uses part of the integrated household water consumption model by Jorgensen, Graymore, and O'Toole (2009, 233). This model integrates various theoretical frameworks with "conservation intention" as a key factor behind consumption (see also Russell and Knoeri 2020, 942). Figure 2 shows how part of the model was used as denoted by the shaded constructs and black arrows, with bullets indicating the variables included in the WDM study to measure each construct.

As shown in Figure 2, "conservation intention" was measured as intended uptake of rainwater harvesting, permeable paving and greywater reuse systems. Thus, it was hypothesised that intended uptake would be predicted by the various factors behind conservation, such as demographics, household composition, dwelling characteristics, attitudes toward restrictions, and water-use behaviour. Uptake of WSUD measures, or

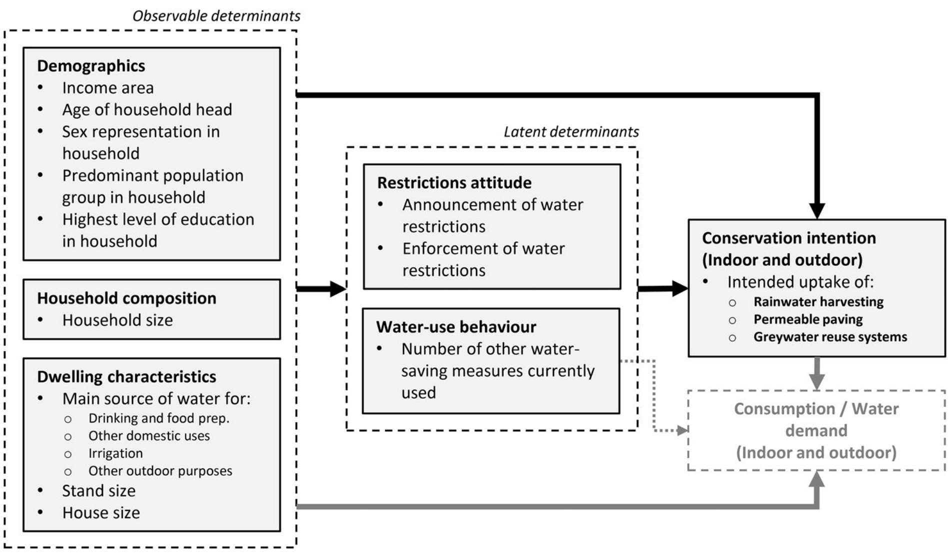

Figure 2. Theoretical framework.
Source: Adapted from Jorgensen *et al*. (2009, 233).

at least aspects thereof, appears to be associated with environmental behaviour (Ahmed, Parker, and Drescher 2025), demographics such as income, education and home ownership (Fox, McIntosh, and Jeffrey 2009; Brown *et al*. 2016; Cockerill *et al*. 2019; Ahmed, Parker, and Drescher 2025), and household size (Fox, McIntosh, and Jeffrey 2009), as well as dwelling characteristics such as stand size (Brown *et al*. 2016; Ahmed, Parker, and Drescher 2025) and house size (Fox, McIntosh, and Jeffrey 2009).

The present study therefore tested the extent to which the 15 predictors of conservation intention could explain intended uptake. In recent studies, demographics, household composition and dwelling characteristics were termed "observable" determinants of consumption, and attitudes toward restrictions and water-use behaviour were termed "latent" determinants (Cominola *et al*. 2023). Using the integrated household water consumption model could simultaneously contribute to a better understanding of how to study uptake of WSUD measures in the context of WDM, and the extent to which predictors of conservation intention may explain intended uptake.

3. Research design and methods

The present study focused on the Gauteng city region in the interior of South Africa. Although geographically the smallest, Gauteng currently has the highest urbanisation rate and is the most populated province with approximately 15.1 million people. It is the economic centre of South Africa and responsible for a third of the national gross domestic product (Statistics South Africa 2024). The region has warm summers with thunderstorms and cold, dry winters. The average annual rainfall is 785 mm compared to a global average of 990 mm (Climate-Data.org 2013; Department of Water Affairs 2013). Gauteng is largely made up of three metropolitan areas, as per Figure 1, namely, Johannesburg, Ekurhuleni (the East Rand), and Tshwane (Pretoria). Each of these areas were included in a cross-sectional household survey as part of the CSIR's WDM study.

The CSIR liaised with each municipality to compile a cluster sample (Ormrod 2024) of predominantly residential neighbourhoods from historically designated "white" suburbs and "black" townships, considering enduring social, economic and environmental differences between these settlement types that might influence WDM and WSUD (see, e.g. Carden *et al*. 2018, 9). Suburbs were purposefully sampled according to different income areas and levels of water consumption (see, e.g. Murwirapachena 2021). Ethical clearances for the survey were obtained from the Research Ethics Committee of the CSIR (Ref. 240/2017) and of the University of Pretoria's Faculty of Engineering, Built Environment and Information Technology (Ref. EBIT/43/2018).

The CSIR facilitated a fieldwork preparation workshop attended by CSIR and student fieldworkers. During the workshop, the survey and questionnaire were discussed, mock interviews were conducted, and fieldwork and safety protocols were established. The survey questionnaire provided definitions of rainwater harvesting,[1] permeable paving[2] and greywater reuse systems,[3] then asked respondents whether they used each "this time last year" (provided they did not move house over the last 12 months), "now", or would use it "this time next year" (provided they did not plan to move house over the next 12 months).

Fieldwork teams consisting of at least one CSIR and one student fieldworker surveyed 200 households in each municipality during late winter and early spring of 2019, using a convenient door-to-door sample within each cluster. The fieldwork team approach and use of CSIR-branded vehicles and clothing ensured the safety and credibility of fieldworkers amidst high levels of crime and distrust in South Africa. Fieldworkers interviewed heads of households or household members identified as most suitable for the purposes of the study, for example, members older than 18 and primarily involved in activities such as cooking, washing or gardening (see, e.g. Baiyegunhi 2014). The CSIR conducted quality checks at the end of each day to determine any inconsistencies in the completion of questionnaires.

Following quality checks for inconsistencies, data were exported to IBM's Statistical Package for the Social Sciences (SPSS) (Version 30). Considering the focus on uptake of WSUD measures, the findings presented here are based on a subsample of 375 households; that is, 125 from each municipality disaggregated by 90 suburban and 35 township households. The subsample included households who occupied freestanding houses and single-storey duplexes, owned their dwelling, and relied on municipal, borehole or bottled water as their main source of potable water. The subsample included home owners only, considering that they were more likely than tenants to invest in WSUD measures (Ahmed, Parker, and Drescher 2025). Given nominal and ordinal levels of measurement, data were analysed using chi-square tests, standardised residuals, and measures of association for effect size. Binary logistic regressions were used to determine the percentage variance explained by significant predictors.

4. Findings

Findings are first presented in terms of de facto past, present, and future intended uptake and the influence of settlement type on uptake. Next, the effect of predictors of water conservation intention on intended uptake in suburbs is examined. Findings from a follow-up analysis are then presented. The findings are simultaneously discussed in this section, followed by proposed directions for more systematic research.

4.1. De facto past, present, and future intended uptake and the influence of settlement type

The first aim was to determine de facto past, present, and future intended uptake of WSUD measures, as well as the influence of settlement type on uptake. Table 1 shows de facto past, present, and future intended uptake of these measures among home owners by settlement type based on the proportion of households that reported uptake. The influence of settlement type on uptake was determined using chi-square tests, standardised residuals, and phi for effect size considering 2×2 tables (Field 2018). For each chi-square test, all expected counts were > 5 ($df = 1$).

In terms of de facto past, present, and future intended uptake, and as shown in Table 1, the highest percentage of total present uptake was in respect of rainwater harvesting (22%), followed by greywater reuse systems (20%) and permeable paving (16%). Uptake was, however, self-reported, and responses were probably subject to some degree of social desirability bias (i.e. the tendency to overstate socially desirable behaviour in the presence of a fieldworker) (Ormrod 2024). In fact, lower levels of de facto uptake of rainwater harvesting (16%) and permeable paving (7%) are reported in

Table 1. De facto past, present, and future intended uptake of water-sensitive urban design (WSUD) measures among home owners by settlement type.

WSUD measure	Period	Suburb		Township		Total		Sig.	Phi
		Count	%	Count	%	Count	%		
Rainwater harvesting	Past	46	24.6	14	12.5	60	20.1	$p = 0.011$**	0.146**
	Present	52	27.8	15	13.4	67	22.4	$p = 0.004$***	0.167***
	Future	70	37.4	15	13.4	85	28.4	$p < 0.001$***	0.258***
Permeable paving	Past	36	19.3	11	9.8	47	15.7	$p = 0.030$**	0.125**
	Present	38	20.3	11	9.8	49	16.4	$p = 0.018$**	0.137**
	Future	39	20.9	11	9.8	50	16.7	$p = 0.013$**	0.143**
Greywater reuse systems	Past	44	23.5	16	14.3	60	20.1	$p = 0.053$*	0.112*
	Present	44	23.5	17	15.2	61	20.4	$p = 0.083$*	0.100*
	Future	58	31.0	17	15.2	75	25.1	$p = 0.002$***	0.177***

Note: Significant at the *0.1, **0.05 and ***0.01 levels respectively.

more developed countries (Cockerill *et al*. 2019). Fieldworkers also suspected that some respondents, especially township and non-English-speaking respondents, might have reported manual greywater recycling rather than reuse systems that would have required retrofitted plumbing. Uptake of greywater reuse systems is, therefore, likely to be lower. Rainwater harvesting was expected to increase to 28% the following year, followed by greywater reuse systems (25%), whereas permeable paving was expected to increase marginally. These intended levels of uptake are, on the other hand, much lower compared to intended levels of uptake of rainwater harvesting or permeable paving (50–70%) in more developed countries (Dean *et al*. 2023). The structural and socio-economic challenges associated with a developing country, and townships in particular, most likely contributed to much lower levels of intended uptake.

According to the household water consumption model in Figure 2, "conservation intention", conceptualised here as intended uptake of WSUD measures, directly influences water demand. Thus, the model suggests that the levels of uptake reported in this survey, although probably somewhat overstated, may hold important implications for WDM in South Africa. Water managers and planners may increasingly have to factor in the role of WSUD measures at household level as part of WDM. Moreover, the levels of uptake suggest the viability of planning for WSUD at site level and assisting households to adopt WSUD measures, which may further positively influence WDM.

In terms of the influence of settlement type on uptake, suburbs showed significantly higher levels of de facto past, present and future intended uptake of all three measures than townships, especially intended uptake of rainwater harvesting (37% as opposed to 28%, $p < 0.001$, phi = 0.258). Although influences were small (except for the influence on intended uptake of rainwater harvesting), these differences in uptake were statistically significant. Standardised residuals suggested that the strongest contributor to these influences was the significantly lower than expected number of township households that reported current (−2.0, $p < 0.05$) and intended (−3.0, $p < 0.01$) uptake of rainwater harvesting and intended uptake of greywater reuse systems (−2.1 $p < 0.05$).

Differences in uptake could arguably be ascribed to structural differences and differences in socio-economic conditions between suburbs and townships, as well as lower levels of trust in townships due to South Africa's segregated past. Trust is key to conservation, and positive expectations of institutions and others' behaviour form part of this trust (Jorgensen, Graymore, and O'Toole 2009). Many township households historically distrust local government and perceive low levels of conservation around them, which might have contributed to a reluctance to conserve, let alone adopt WSUD measures. Moreover, the South African Government's policy to provide free water of up to 6 kl per month to an indigent household (Cooperative Governance and Traditional Affairs Ministry 2022) might have contributed to lower levels of uptake in townships. Uptake in townships is critical because townships form a large and growing part of the South African urban landscape (Statistics South Africa 2024). Clearly, WSUD measures are important to achieve water sensitivity in both suburbs and townships, but they may need to be planned and implemented differently in these two settlement types.

4.2. The effect of predictors of water conservation intention on intended uptake

The second aim was to determine the effect of predictors of water conservation intention on intended uptake of WSUD measures. As shown in Figure 2, the WDM study included 15 predictors of "conservation intention" and hence of intended uptake of WSUD measures. Table 2 shows significant predictors ($p \leq 0.1$) of intended uptake of each of the three WSUD measures among home owners in suburbs, sorted by effect size. The analysis included suburbs only as there were higher levels of uptake and as some predictors were more applicable to or varied in suburbs. Examples of such predictors were the main source of water (municipal vs borehole) and the size of the stand and the house. The effect of predictors was determined using chi-square tests, standardised residuals, and Cramér's V for effect size considering the larger tables (Field 2018). For each chi-square test with a 2×2 table, all expected counts were > 5 ($df = 1$), and for each chi-square test with a larger table, all expected counts were > 1, and more than 20% of expected counts were > 5 ($df = 2$).

Table 2 shows that intended uptake of all three measures were most strongly predicted by the number of other water-saving measures that were used at the time, such as smart metering, timed sprinklers, constant flow regulators, dual-flush toilets, water-saving shower heads, and eco settings on appliances. The more water-saving techniques used, the more likely households were to report intended use of rainwater harvesting ($p < 0.001$, Cramér's $V = 0.377$), permeable paving ($p = 0.009$, Cramér's $V = 0.230$) and greywater reuse systems ($p < 0.001$, Cramér's $V = 0.309$). Standardised residuals, however, suggested that the strongest contributor to the overall effect was not so much an increase in the number of other water-saving measures used, but the significantly lower than expected uptake of rainwater harvesting (-3.1, $p < 0.01$), permeable paving (-2.1, $p < 0.01$) and greywater reuse systems (-2.6 $p < 0.01$) among households that did not use *any* other water-saving measures.

This finding highlights the normative or reinforcing nature of pro-environmental behaviour. Once simpler practices are used, it leads to more complex practices. Environmental awareness and other forms of pro-environmental behaviour have, in fact, been shown to predict uptake of WSUD measures in more developed countries, especially rainwater harvesting (Ando and Freitas 2011; Gao *et al.* 2016; Conway *et al.* 2023).

The highest level of education in the household was the second strongest predictor of rainwater harvesting and permeable paving, although effect sizes were small. A significantly higher percentage of "undergraduate" households (45%) intended to harvest rainwater compared to "schooled" (19%) and "postgraduate" (38%) households ($p = 0.036$, Cramér's

Table 2. Significant predictors of intended uptake of water-sensitive urban design (WSUD) measures among home owners in suburbs.

WSUD measure	Predictor	Predictor category (proportion of households reporting uptake)	Chi-square	Cramér's V
Rainwater harvesting	Number of other water-saving measures currently used	None (9.1%) One or two (37.5%) Three or more (55.9%)	$\chi^2(2, 176) = 24.955$, $p < 0.001$***	0.377***
	Highest level of education in household	No/some schooling or Grade 12 (18.8%) Undergraduate or college (45.2%) Postgraduate (38.2%)	$\chi^2(2, 181) = 6.658$, $p = 0.036$**	0.192**
Permeable paving	Number of other water-saving measures currently used	None (6.8%) One or two (20.3%) Three or more (30.9%)	$\chi^2(2, 176) = 9.348$, $p = 0.009$***	0.230***
	Highest level of education in household	No/some schooling or Grade 12 (6.3%) Undergraduate or college (27.4%) Postgraduate (21.1%)	$\chi^2(2, 181) = 5.999$, $p = 0.050$*	0.182*
Greywater reuse systems	Number of other water-saving measures currently used	None (9.1%) One or two (29.7%) Three or more (45.6%)	$\chi^2(2, 176) = 16.778$, $p < 0.001$***	0.309***

Note: Significant at the *0.1, **0.05 and ***0.01 levels respectively.

$V = 0.192$). Similarly, a significantly higher percentage of "undergraduate" households (27%) intended to use permeable paving compared to "schooled" (6%) and "postgraduate" (21%) households ($p = 0.050$, Cramér's $V = 0.182$). The level of intended uptake among water-saving and "undergraduate" households in suburbs is, thus, much closer to that in more developed countries (Dean *et al.* 2023).

Tertiary education could probably be associated with higher levels of environmental awareness and technical knowhow, which in turn are associated with uptake of WSUD measures (Conway *et al.* 2023). Although tertiary education contributed to intended uptake of rainwater harvesting and permeable paving, the relationship was non-linear. Compared to undergraduate education, postgraduate education could be associated with higher income. Thus, compared to "undergraduate" households, "postgraduate" households might have had less economic incentive to harvest rainwater. It was also likely that they were located in more upmarket developments where it was not permitted to harvest rainwater or use permeable paving because of restrictive rules or building codes (Funke *et al*. 2017). These findings corroborate findings regarding the nonlinear relationship between income and uptake in more developed countries (Cockerill *et al*. 2019). Targeted awareness and educational campaigns or subsidised schemes would be important to support uptake among households without tertiary education. Motivating or incentivising uptake among "postgraduate" or more affluent households would also be important, especially in upmarket developments where motivating or incentivising initiatives would have to occur through managing agencies or home owner associations (Lawton, Birchfield, and Wilson 2008).

Of the 15 predictors included in the WDM study, only two (water-saving behaviour and education) appeared to be meaningfully associated with intended uptake of WSUD measures. Moreover, binary logistic regressions showed that these two predictors together explained only 17 to 24% of the variance in intended uptake for rainwater harvesting ($\chi^2(4,\ 170)\ =\ 32.202$, $p < 0.001$), 8 to 12% for permeable paving ($\chi^2(4,\ 170)\ =\ 13.585$, $p = 0.009$) and 11 to 15% for greywater reuse systems ($\chi^2(4,\ 170)\ =\ 19.026$, $p < 0.001$). For all three regressions, variance inflation factors were ≤ 3.033 and the Hosmer and Lemeshow test significance was ≥ 0.605. Uptake could more likely be better explained by predictors other than some of those included in the WDM study. These predictors may differ between measures (Ahmed, Parker, and Drescher 2025) and involve more complex and context-specific interactions. More systematic research is clearly needed, which is proposed later on in the article.

Of interest was the much larger effect of water-saving behaviour on intended uptake of all three WSUD measures, as opposed to any of the other predictors. The household water consumption model might suggest that the effect of water-use behaviour on conservation could be moderated or mediated by demographics, household composition or dwelling characteristics, though Jorgensen, Graymore and O'Toole (2009) do not mention it. Moderation and mediation analyses in SPSS using interaction terms and the add-in *PROCESS* tool (Version 4.2) showed no significant moderation or mediation in this study. A follow-up analysis, reported in Section 4.3, was conducted to determine the effect of demographics, household composition and dwelling characteristics on water-saving measures, assuming they might affect uptake indirectly through water-use behaviour. Attitudes toward restrictions were not analysed considering they had no significant effect in this study. Other studies corroborate the limited effect of water restrictions in South Africa (Funke *et al*. 2017).

4.3. The effect of demographics, household composition and dwelling characteristics on the use of other water-saving measures

Table 3 shows significant predictors ($p \leq 0.1$) of the number of other water-saving measures that home owners in suburbs used, sorted by effect size. Again, the effect was determined using chi-square tests, standardised residuals, and Cramér's V for effect size. All expected counts were > 1, and more than 20% of expected counts were > 5 ($df = 2 \mid 4$).

Table 3 shows that other water-saving measures were most strongly predicted by the main source of water for (1) drinking and food preparation ($p < 0.001$, Cramér's $V = 0.324$), (2) irrigation ($p = 0.029$, Cramér's $V = 0.233$) and (3) other outdoor purposes ($p = 0.031$,

Table 3. Significant predictors of the number of other water-saving measures currently used among home owners in suburbs.

Predictor	Predictor category (combined proportion of households reporting one or more other water-saving measures as opposed to none)	Chi-square	Cramér's *V*
Main source of water for drinking and food preparation	Municipal (81.1%) Borehole or other (42.9%)	$\chi^2(2, 176) = 18.499$, $p < 0.001$***	0.324***
Main source of water for irrigation	Municipal (80.9%) Borehole or other (66.6%)	$\chi^2(2, 131) = 7.096$, $p = 0.029$**	0.233**
Main source of water for other outdoor purposes	Municipal (80.6%) Borehole or other (61.6%)	$\chi^2(2, 142) = 6.965$, $p = 0.031$**	0.221**
Income area	Middle (70.4%) Mixed (middle to high) (83.6%) High (59.2%)	$\chi^2(4, 173) = 9.167$, $p = 0.057$*	0.163*
Age of head of household	Younger than 45 (81.9%) 45–65 (71.8%) Older than 65 (74.1%)	$\chi^2(4, 168) = 8.963$, $p = 0.062$*	0.163*
Household size	One to three members (75.0%) Four members (64.1%) More than four members or multiple families (84.0%)	$\chi^2(4, 173) = 8.215$, $p = 0.084$*	0.154*

Note: Significant at the *0.1, **0.05 and ***0.01 levels respectively.

Cramér's $V = 0.221$). A significantly higher percentage of households relying on municipal water for all three of these purposes used other water-saving measures as opposed to households relying on boreholes or other sources of water. Standardised residuals also suggested that the strongest contributor to these effects was the significantly higher than expected *lack* of water saving among households relying on boreholes (3.4, $p < 0.001$).

Rapid infrastructural decline and increasing municipal water supply disruptions in South Africa (Carden *et al*. 2018) arguably contributed to the increased use of other water-saving measures by households reliant on municipal water. Considering the strong association between other water-saving measures and intended uptake of WSUD measures, households reliant on municipal water could possibly also consider rainwater harvesting and greywater reuse systems to reduce their reliance on municipal water. Unreliable municipal water supply could therefore eventually drive households towards uptake. The low level of water-saving measures among borehole users is concerning, as groundwater is a fragile and finite resource.

Income, the age of the household head and the size of the household were also significant predictors, although effect sizes were small and non-linear. Middle-income, younger or larger households could possibly also consider WSUD measures, though chances are small.

While there is value in studying uptake in the context of WDM by conceptualising uptake as a form of conservation, a better understanding is still needed about what predicts uptake, let alone how to plan for and manage uptake at site level. This suggests the need for more systematic research into not only the nature of uptake, but also the praxis thereof by experimenting with the implementation of WSUD measures and learning from what works in practice.

5. Directions for more systematic research

As argued above, more systematic research is needed not only into the nature of uptake of WSUD measures, but also the facilitation thereof. Table 4 shows three

Table 4. Directions for more systematic research on household uptake of water-sensitive urban design (WSUD) measures.

	Direction		
Consideration	1	2	3
Disciplinary involvement	Multi-disciplinary/ interdisciplinary	Multi-disciplinary/ interdisciplinary	Transdisciplinary
Conceptual or theoretical framework	Diffusion of innovations (DOI)	Integrated household water consumption model Theory of planned behaviour (TPB)	Shared conceptual frameworks based on systemic and relational thinking
Mode of reasoning	Inductive (theory-generating)	Deductive (theory-testing)	Praxis (experimenting with theory)
Main research question	*What meanings do householders attach to a water-sensitive city, the urban water cycle and WSUD measures, and which factors appear to affect uptake of these measures?*	*What is the relative effect of different factors on household uptake of WSUD measures, and what are the implications for the facilitation of uptake?*	*How do we facilitate household uptake of WSUD measures to minimise the impact of the urban water cycle and move towards a water-sensitive city?*
Research purpose	Exploratory Descriptive	Explanatory Predictive	Intervention Evaluation
Methodological paradigm	Interpretivism	Post-positivism	Critical realism Pragmatism
Methodological approach	Qualitative	Quantitative	Multi-method/mixed-method
Research design (and core logic)	Field research (phenomenology/ ethnography) Grounded theory (induction)	Survey (generalisation/ correlation) Field experiment (causal attribution)	Participatory action research (participation) Intervention and evaluation research (intervention/ evaluation)

possible directions for more systematic research that may help to integrate the growing body of research.

5.1. Direction 1: multi-disciplinary/interdisciplinary qualitative research

Interpretivism holds that uptake is based on the *meanings* householders attach to the notions of a water-sensitive city, the urban water cycle and WSUD measures (Buurman and Padawangi 2018; Dean *et al*. 2023). The main research question here may concern what these meanings are, and the purpose of research may be to explore and describe these meanings as well as various factors that appear to affect uptake. Sections 4.2 and 4.3 suggested the need to consider different or more context-specific factors other than those in the WDM study. An applicable conceptual framework is, for example, diffusion of innovations (DOI) (Rogers 2003), which focuses on how new technologies are taken up in society. According to DOI, sense-making and uptake of WSUD measures depend on attributes such as relative advantage, compatibility, complexity, observability and trialability, as shown in a qualitative study by Dean *et al*. (2023). In another qualitative study, Leonard *et al*. (2019) identified factors such as cost, technical knowhow, perceived effectiveness and institutional trust.

Field research may include phenomenology (how householders make sense of and experience water-related issues), and ethnography (the cultural practices around water), using methods such as in-depth interviewing and participatory observation in natural settings. Grounded theory may either generate theory or identify other applicable conceptual or theoretical frameworks. Direction 1 contributes to gaining an understanding of meanings and practices around water, and generates theory for quantitative research.

5.2. Direction 2: multi-disciplinary/interdisciplinary quantitative research

Post-positivism holds that uptake is predicted by *factors* at aggregated levels, and that planners ought to use such factors to nudge households towards uptake (Westin and Joosse 2022). The main research question here may be what the relative effect is of different factors on uptake, and the purpose may be to explain and predict uptake and to identify implications for facilitating uptake.

Applicable theoretical frameworks are, for example, the integrated household water consumption model (Jorgensen, Graymore, and O'Toole 2009) and the theory of planned behaviour (TPB) (Ajzen 2020). The integrated household water consumption model includes factors in addition to those in the WDM study that may better predict uptake. These include outdoor interest and use, perceived risk of shortages, and institutional trust and fairness (Jorgensen, Graymore, and O'Toole 2009). According to Leonard *et al*. (2019), perceived effectiveness and institutional trust would be critical if households were to be nudged towards uptake or assisted to implement WSUD measures. The model also factors in the TPB, although the TPB is often used as a standalone framework for studies on pro-environmental behaviour.

According to the TPB, uptake is predicted by attitude, subjective norm and perceived behavioural control, the latter being ability. Because the TPB is a well-validated theory of pro-environmental behaviour, it can be assumed that uptake is probably predicted by positive attitudes and norms (Brown *et al*. 2016), as shown in quantitative studies by Shin and McCann (2018) and Du Toit and Wagner (2022). Further research is, however, needed on householders' *ability* to adopt WSUD measures, and the extent to which this is a factor of, for example, cost, technical knowhow (Leonard *et al*. 2019), site and dwelling characteristics (Du Toit and Wagner 2022), long term maintenance (Conway *et al*. 2023) or public–private partnerships (Funke *et al*. 2017; Cockerill *et al*. 2019).

Applicable research designs may be surveys or field experiments using methods such as standardised questionnaires. In the CSIR's WDM survey, however, refusal rates were high due to restricted access, low levels of trust amidst high levels of crime, and the unavailability of many household heads during daytime. Social desirability bias probably also inflated pro-environmental responses. These limitations can be mitigated if municipalities provide ratepayer data to enable larger online surveys (see, e.g. Cockerill *et al*. 2019) and weighting of non-probability samples. Other WSUD measures applicable at site level may also be studied, such as soakaways (Armitage *et al*. 2014) and detention/retention ponds in settings with larger stands lacking stormwater infrastructure (Du Toit and Wagner 2022). There is also a need for longitudinal surveys following awareness campaigns or subsidised/incentivised programmes.

Direction 2 tests theory, and contributes to an instrumental understanding of the causal factors behind uptake, enabling the nudging of households towards uptake or informing the facilitation thereof.

5.3. Direction 3: transdisciplinary multi-method/mixed-method research

Critical realism holds that there are multiple realities around uptake, and that researchers should mediate these realities, facilitate participation, and address real-world problems to bring about positive change (Westin and Joosse 2022). Transdisciplinarity requires researchers to bridge the gap between research and practice. The main research question here may be how to *facilitate* uptake to minimise the impact of the urban water cycle and move towards a water-sensitive city. Shared conceptual frameworks that encapsulate systemic thinking (Chadfield, Wei, and Lieske 2024) and relational thinking (Lawrence 2021) may inform research, implementation and participation between various stakeholders.

The research purpose may be to intervene in the urban water cycle by researching and implementing WSUD measures, monitoring implementation, and evaluating outcomes. Pragmatism suggests flexibility and plurality in terms of research designs and methods, as long as project objectives are met and research enables participation, intervention and evaluation (Du Toit, Pieterse, and Mbatha 2025). Because suburban households may view stormwater runoff as a public rather than a private issue (Turner, Jarden, and Jefferson 2016), participatory action research may, for example, follow an awareness or educational approach to emphasise the relevance of WSUD. Awareness or educational programmes may help householders to visualise the advantages of WSUD for both themselves and the urban water cycle and to identify the support needed for adoption (Brown *et al*. 2016; Dean *et al*. 2023). Intervention research may include drawing up WSUD frameworks to integrate regional and local stormwater controls into spatial planning and land-use management at various scales (Cilliers and Rohr 2019; Fourie *et al*. 2020; Gober *et al*. 2013). Such frameworks may align and coordinate the involvement of municipalities and resident associations, and support or incentivise households to adopt stormwater controls in a more integrated manner (Lawton, Birchfield, and Wilson 2008; Turner and Ibes 2011). While the literature on WSUD uptake shows signs of transdisciplinarity by virtue of reporting incentivised programmes and blending social and environmental sciences with planning and design (see, e.g. Brown *et al*. 2016), there is still a need for greater community co-production and design.

Direction 3 experiments with theory, and contributes not only to gaining a practical understanding of uptake through "knowing-in-practice" (Lawrence 2021, 117), but also to taking an actual step towards more water-sensitive cities.

6. Conclusion

The present study determined household uptake of WSUD measures in the context of an applied WDM study, and identified predictors of uptake using an integrated household water consumption model in which uptake was conceptualised as a form of conservation. Current and intended uptake of rainwater harvesting, greywater reuse systems, and, to a lesser extent, permeable paving, was noticeable among water-saving suburban households with tertiary education, but less so among township households. The levels of uptake suggested the viability of planning for WSUD measures and tailoring them according to settlement type.

Apart from the effect of water-saving behaviour and education, uptake may be influenced indirectly as households seek to reduce their reliance on municipal water amidst increasing unreliability of supply. Other predictors of conservation, however, offered limited explanation of intended uptake, suggesting the need for more systematic research into both the nature and facilitation of uptake. Three directions for more systematic research were therefore identified, namely, multi-disciplinary/interdisciplinary qualitative and quantitative research, and transdisciplinary multi-method/mixed-method research. Each direction may offer a unique contribution, and all are of equal importance. They complement each other and together may produce a more coordinated and integrated body of research.

In terms of the transition of urban water management towards water-sensitive cities, the present study highlighted how uptake of WSUD measures is not just a technical choice, but also an indication of the socio-institutional transition that would be necessary. The study contributes to the broader discourse on WSUD by examining how household-level intentions shape the micro-level foundations of this transition in a developing country context. By comparing uptake across suburbs and townships, the study offers insights into how structural inequality may mediate the hydro-social contract, shaping the discourse for more inclusive water-sensitive cities in South Africa.

Notes

1. Defined as "the collection of rainwater from roofs into storage tanks, e.g., JoJo tanks".
2. Defined as "using sustainable materials and techniques that allows water to seep through the paving into the ground".
3. Defined as "retrofitting plumbing in order to reuse water from bathroom basins, baths and showers, or kitchen sinks and dishwashers, or laundry basins and washing machines for irrigation, flushing toilets, outdoor purposes, etc.".

Acknowledgements

The author would like to thank the CSIR for the logistical support relating to the fieldwork, and the students who participated as fieldworkers as part of their final-year research report for the bachelor's degree in Town and Regional Planning at the University of Pretoria. These students were Lethabo Chilwane, Pavlo Eftychis, Lawrence Fowle, Adam Harper, Dylan Laloux, Akani Mabasa, Anthonia Mabotsa, Khanyisile Mabunda, Mmashibu Mashiane, Tebogo Mekgwe, Anelisiwe Mvubu, Matshidiso Raganya, and Melissa Taleni. The author would also like to thank Lourens Snyman from the University of Pretoria's Department of Geography, Geoinformatics and Meteorology for creating the map in Figure 1, and the three reviewers whose comments helped to significantly improve the article.

Disclosure statement

No potential conflict of interest was reported by the author.

ORCID

Jacques du Toit http://orcid.org/0000-0002-9589-4128

References

Ahmed, Hazem, Dawn C. Parker, and Michael Drescher. 2025. "Adoption Determinants and Policy Tools for Residential Green Stormwater Infrastructure: A Review Synthesizing Differences and Commonalities among Lot-Level Practices." *Journal of Environmental Management* 373: 123279. doi:10.1016/j.jenvman.2024.123279.

Ajzen, Icek. 2020. "The Theory of Planned Behavior: Frequently Asked Questions." *Human Behavior and Emerging Technologies* 2 (4): 314–324. doi:10.1002/hbe2.195.

Ando, Amy W., and Luiz P. C. Freitas. 2011. "Consumer Demand for Green Stormwater Management Technology in an Urban Setting: The Case of Chicago Rain Barrels." *Water Resources Research* 47 (12): W12501. doi:10.1029/2011WR011070.

Armitage, Neil, Lloyd Fisher-Jeffes, Kirsty Carden, Kevin Winter, Vinothan Naidoo, Andrew Spiegel, Ben Mauck, and Daniel Coulson. 2014. *Water Sensitive Urban Design (WSUD) for South Africa: Framework and Guidelines* (WRC Report No. TT 588/14). Research Report. Urban Water Management Research Unit, University of Cape Town. Pretoria: Water Research Commission. http://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/TT%20588-13.pdf.

Baiyegunhi, Lloyd James S. 2014. "Determinants of Rainwater Harvesting Technology (RWHT) Adoption for Home Gardening in Msinga, KwaZulu-Natal, South Africa." *Water SA* 41 (1): 33–40. doi:10.4314/wsa.v41i1.6.

Brown, Helen L., Darren G. Bos, Christopher J. Walsh, Tim D. Fletcher, and Sharyn RossRakesh. 2016. "More than Money: How Multiple Factors Influence Householder Participation in At-Source Stormwater Management." *Journal of Environmental Planning and Management* 59 (1): 79–97. doi:10.1080/09640568.2014.984017.

Brown, Rebekah R., Nina Keath, and Tony H. F. Wong. 2009. "Urban Water Management in Cities: Historical, Current and Future Regimes." *Water Science and Technology: A Journal of the International Association on Water Pollution Research* 59 (5): 847–855. doi:10.2166/wst.2009.029.

Buurman, Joost, and Rita Padawangi. 2018. "Bringing People Closer to Water: Integrating Water Management and Urban Infrastructure." *Journal of Environmental Planning and Management* 61 (14): 2531–2548. doi:10.1080/09640568.2017.1404972.

Carden, Kirsty, Neil Armitage, Lloyd Fisher-Jeffes, Kevin Winter, Benjamin Mauck, Tom Sanya, Preetya Bhikha, Greg Mallett, Thokozani Kanyerere, and Siyamthande Gxokwe. 2018. *Challenges and Opportunities for Implementing Water Sensitive Design in South Africa*. Report. Urban Water Management, University of Cape Town. Pretoria: Water Research Commission. https://www.wrc.org.za/wp-content/uploads/mdocs/2412-181.pdf

Carmon, Naomi, and Uri Shamir. 2010. "Water-Sensitive Planning: Integrating Water Considerations into Urban and Regional Planning." *Water and Environment Journal* 24 (3): 181–191. doi:10.1111/j.1747-6593.2009.00172.x.

Chadfield, Sian J., Yongping Wei, and Scott N. Lieske. 2024. "Water Sensitive Communities: A Systematic Review with a Complex Adaptive Systems Perspective." *Journal of*

Environmental Planning and Management 67 (5): 1077–1103. doi:10.1080/09640568.2022.2147421.

Cilliers, Elizelle J., and Hildegard E. Rohr. 2019. “Integrating WSUD and Mainstream Spatial Planning Approaches: Lessons from South Africa.” Chap. 17 In *Approaches to Water Sensitive Urban Design*, edited by Ashok K. Sharma, Ted Gardner, and Don Begbie, 351–366. Amsterdam: Elsevier. doi:10.1016/B978-0-12-812843-5.00017-4.

City of Johannesburg Metropolitan Municipality. 2024. *Spatial Development Framework 2040*. Department of Development Planning, Johannesburg: City of Johannesburg Metropolitan Municipality. https://joburg.org.za/documents_/Pages/Key%20Documents/Draft-Spatial-Framework-2040.aspx.

Climate-Data.org. 2013. *Climate: Gauteng*. Accessed September 27, 2024. https://en.climate-data.org/africa/south-africa/gauteng-539/.

Cockerill, Kristan, Tanga Mohr, William P. Anderson, Jr, Peter Groothuis, Chuanhui Gu, and John Whitehead. 2019. “Managing Stormwater Runoff in Appalachia: What Does the Public Think?” *Journal of Environmental Planning and Management* 62 (14): 2418–2436. doi:10.1080/09640568.2018.1559803.

Cominola, Andrea, Lucy Preiss, Mark Thyer, Holger R. Maier, Peter Prevos, Raj A. Stewart, and Andrea Castelletti. 2023. “The Determinants of Household Water Consumption: A Review and Assessment Framework for Research and Practice.” *Npj Clean Water.*6 (1): 11. doi:10.1038/s41545-022-00208-8.

Conway, Tenley M., Annie Y. Yuan, Lara A. Roman, Megan Heckert, Hamil Pearsall, Stephen T. Dickinson, Christina D. Rosan, and Camilo Ordóñez. 2023. “Who Participates in Green Infrastructure Initiatives and Why? Comparing Participants and Non-Participants in Philadelphia’s GI Programs.” *Journal of Environmental Policy & Planning* 25 (3): 327–341. doi:10.1080/1523908X.2022.2128310.

Cooperative Governance and Traditional Affairs Ministry. 2022. *How Do I Access Free Basic Municipal Services?* Accessed December 26, 2024. https://www.cogta.gov.za/index.php/2021/04/11/how-do-i-access-free-basic-municipal-services/.

Dean, Angela J., Fiona J. Newton, Robyn E. Gulliver, Kelly S. Fielding, and Helen Ross. 2023. “Accelerating the Adoption of Water Sensitive Innovations: Community Perceptions of Practices and Technologies to Mitigate Urban Stormwater Pollution.” *Journal of Environmental Planning and Management* 66 (4): 759–778. doi:10.1080/09640568.2021.2002279.

Department of Water Affairs. 2013. *National Water Resource Strategy: Water for an Equitable and Sustainable Future*. 2nd ed. Pretoria: Department of Water Affairs. https://www.dws.gov.za/documents/Other/Strategic%20Plan/NWRS2-Final-email-version.pdf.

Du Toit, Jacques, Amy Pieterse, and Sandile Mbatha. 2025. “A Methodological Framework for Transdisciplinary Urban Planning.” In *Spatial Methods in Transdisciplinarity for Urban Sustainability: Sustainable Development Goals Series*, edited by Fraya Frehse, Angela Million, and Ignacio Castillo Ulloa, 3–17. Cham: Springer. doi:10.1007/978-3-031-84367-9_1.

Du Toit, Jacques, and Claire Wagner. 2022. “Property Owners’ Uptake of Stormwater Source Controls: A Case Study of a Low-Density Upmarket Residential Estate in Pretoria, South Africa.” *Urban Water Journal* 19 (5): 538–545. doi:10.1080/1573062X.2022.2035410.

Field, Andy. 2018. *Discovering Statistics Using IBM SPSS Statistics*. 5th ed. London: SAGE Publications Ltd.

Fisher-Jeffes, Lloyd, Kirsty Carden, and Neil Armitage. 2017. “A Water Sensitive Urban Design Framework for South Africa.” *Town and Regional Planning* 71: 1–10. doi:10.18820/2415-0495/trp71i1.1.

Fletcher, Tim D., William Shuster, William F. Hunt, Richard Ashley, David Butler, Scott Arthur, Sam Trowsdale, *et al.* 2015. “SUDS, LID, BMPs, WSUD and More – The Evolution and Application of Terminology Surrounding Urban Drainage.” *Urban Water Journal* 12 (7): 525–542. doi:10.1080/1573062X.2014.916314.

Fourie, Werner, Hildegard E. Rohr, Juanee Cilliers, and Werner Mostert. 2020. *Framework Towards Water-Sensitive Spatial Planning and Land Use Management* (Report no. TT 809/1/20). Research Report. Department of Natural and Agricultural Sciences, Urban and Regional Planning, North West University. Pretoria: Water Research Commission. https://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/TT809-1-19%20final%20web.pdf.

Fox, Clare, Brian S. McIntosh, and Paul Jeffrey. 2009. "Classifying Households for Water Demand Forecasting Using Physical Property Characteristics." *Land Use Policy* 26 (3): 558–568. doi:10.1016/j.landusepol.2008.08.004.

Funke, Nikki, Benita De Wet, Miriam Murambadoro, Ngowenani Nohayi, and Inga Jacobs-Mata. 2017. *A Review of Drivers of and Barriers to Water Conservation Behaviour, and Effective Instruments for Water Demand Side Management - Relevance for Urban Household Water Use in South Africa*. Parliamentary Grant Project Report. Natural Resources and the Environment, Council for Scientific and Industrial Research. Pretoria: Council for Scientific and Industrial Research.

Gao, Yuling, Nicholas Babin, Allison J. Turner, Cheyenne R. Hoffa, Sara Peel, and Linda S. Prokopy. 2016. "Understanding Urban-Suburban Adoption and Maintenance of Rain Barrels." *Landscape and Urban Planning* 153: 99–110. doi:10.1016/j.landurbplan.2016.04.005.

Gober, Patricia, Kelli L. Larson, Ray Quay, Colin Polsky, Heejun Chang, and Vivek Shandas. 2013. "Why Land Planners and Water Managers Don't Talk to One Another and Why They Should!." *Society & Natural Resources* 26 (3): 356–364. doi:10.1080/08941920.2012.713448.

Jorgensen, Bradley, Michelle Graymore, and Kevin O'Toole. 2009. "Household Water Use Behavior: An Integrated Model." *Journal of Environmental Management* 91 (1): 227–236. doi:10.1016/j.jenvman.2009.08.009.

Kampragou, Eleni, Demetris F. Lekkas, and Dionysis Assimacopoulos. 2011. "Water Demand Management: Implementation Principles and Indicative Case Studies." *Water and Environment Journal* 25 (4): 466–476. doi:10.1111/j.1747-6593.2010.00240.x.

Larson, Kelli L., Elizabeth Cook, Colleen Strawhacker, and Sharon J. Hall. 2010. "The Influence of Diverse Values, Ecological Structure, and Geographic Context on Residents' Multifaceted Landscaping Decisions." *Human Ecology* 38 (6): 747–761. doi:10.1007/s10745-010-9359-6.

Lawrence, Roderick J. 2021. *Creating Built Environments: Bridging Knowledge and Practice Divides*. New York: Routledge.

Lawton, Maggie, Damon Birchfield, and Dorothy Wilson. 2008. Slowing the Flow: A Comprehensive Demand Management Framework for Reticulated Water Supply. Ponsonby: Beacon Pathway Limited. https://beaconpathway.co.nz/document/slowing-the-flow-a-comprehensive-demand-management-framework-for-reticulated-water-supply/

Leonard, Rosemary, Sayed Iftekhar, Melissa Green, and Andrea Walton. 2019. "Community Perceptions of the Implementation and Adoption of WSUD Approaches for Stormwater Management." Chap. 24 In *Approaches to Water Sensitive Urban Design*, edited by Ashok K. Sharma, Ted Gardner, and Don Begbie, 499–522. Amsterdam: Elsevier. doi:10.1016/B978-0-12-812843-5.00024-1.

Mankad, Aditi, and Sorada Tapsuwan. 2011. "Review of Socio-Economic Drivers of Community Acceptance and Adoption of Decentralised Water Systems." *Journal of Environmental Management* 92 (3): 380–391. doi:10.1016/j.jenvman.2010.10.037.

Murwirapachena, Genius. 2021. "Understanding Household Water-Use Behaviour in the City of Johannesburg, South Africa." *Water Policy* 23 (5): 1266–1283. doi:10.2166/wp.2021.157.

Ormrod, Jeanne E. 2024. *Practical Research: Design and Process*. Harlow: Pearson.

Pinto, Uthpala, and Basant L. Maheshwari. 2010. "Reuse of Greywater for Irrigation around Homes in Australia: Understanding Community Views, Issues and Practices." *Urban Water Journal* 7 (2): 141–153. doi:10.1080/15730620903447639.

Rashetnia, Simara, Ashok K. Sharma, Anthony R. Ladson, Dale Browne, and Ehsan Yaghoubi. 2022. "A Scoping Review on Water Sensitive Urban Design Aims and Achievements." *Urban Water Journal* 19 (5): 453–467. doi:10.1080/1573062X.2022.2044494.

Rogers, Everett M. 2003. *Diffusion of Innovations*. 5th ed. Riverside: Free Press.

Russell, Sally V., and Christof Knoeri. 2020. "Exploring the Psychosocial and Behavioural Determinants of Household Water Conservation and Intention." *International Journal of Water Resources Development* 36 (6): 940–955. doi:10.1080/07900627.2019.1638230.

Schirmer, Jacki, and Fiona Dyer. 2018. "A Framework to Diagnose Factors Influencing Proenvironmental Behaviors in Water-Sensitive Urban Design." *Proceedings of the National Academy of Sciences of the United States of America* 115 (33): E7690–E7699. doi:10.1073/pnas.1802293115.

Sharma, Ashok K., David Pezzaniti, Baden Myers, Stephen Cook, Grace Tjandraatmadja, Priya Chacko, Sattar Chavoshi, *et al.* 2016. "Water Sensitive Urban Design: An Investigation of Current Systems, Implementation Drivers, Community Perceptions and Potential to Supplement Urban Water Services." *Water* 8 (7): 272. doi:10.3390/w8070272.

Sharma, Ashok K., Ted Gardner, and Don Begbie. 2019. *Approaches to Water Sensitive Urban Design*. Amsterdam: Elsevier. doi:10.1016/C2016-0-03594-5.

Shin, Dong W., and Laura McCann. 2018. "Analyzing Differences among Non-Adopters of Residential Stormwater Management Practices." *Landscape and Urban Planning* 178: 238–247. doi:10.1016/j.landurbplan.2018.06.003.

Statistics South Africa. 2024. *Census 2022*. Accessed September 26, 2024. https://census.statssa.gov.za/#/.

Thurston, Hale W., Michael A. Taylor, William D. Shuster, Allison H. Roy, and Matthew A. Morrison. 2010. "Using a Reverse Auction to Promote Household Level Stormwater Control." *Environmental Science & Policy* 13 (5): 405–414. doi:10.1016/j.envsci.2010.03.008.

Turner, V. Kelly, and Dorothy C. Ibes. 2011. "The Impact of Homeowners Associations on Residential Water Demand Management in Phoenix, Arizona." *Urban Geography* 32 (8): 1167–1188. doi:10.2747/0272-3638.32.8.1167.

Turner, V. Kelly, Kimberly Jarden, and Anne Jefferson. 2016. "Resident Perspectives on Green Infrastructure in an Experimental Suburban Stormwater Management Program." *Cities and the Environment (CATE)* 9 (1): 4. doi:10.15365/1932-7048.1206.

Venkataramanan, Vidya, Denise Lopez, David J. McCuskey, Daniel Kiefus, Robert I. McDonald, William M. Miller, Aaron I. Packman, and Sera L. Young. 2020. "Knowledge, Attitudes, Intentions, and Behavior Related to Green Infrastructure for Flood Management: A Systematic Literature Review." *The Science of the Total Environment* 720: 137606. doi:10.1016/j.scitotenv.2020.137606.

Westin, Martin, and Sofie Joosse. 2022. "Whose Knowledge Counts in the Planning of Urban Sustainability." *Planning Theory & Practice* 23 (3): 388–405. doi:10.1080/14649357.2022.2055118.