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Identifying and understanding the drivers of high water consumption in remote Australian Aboriginal and Torres Strait Island communities

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ABSTRACT

Managing water demand in many remote Indigenous communities is critical yet often poorly implemented due in part to a lack of understanding of the volume and nature of water use. A combination of quantitative and qualitative data has enabled a deeper understanding of water consumption patterns and drivers in three remote Australian communities as part of Stage 1 of the Remote and Isolated Communities Essential Services (RICES) project. Total daily per person use averaged from 270 L/p/d to over 1,500 L/p/d and outdoor water use activities comprised up to 86% of total residential water consumed. Structured interviews with participants identified five main drivers for outdoor water use of which some are traditionally the role of local government service provision (e.g. dust control) and all are closely linked to day to day functioning (e.g. cleaning food, cooling). Traditional demand management strategies such as pricing are not yet appropriate, nor is a reliance on improving local government service provision, due partly to the resource challenges in remote communities. Community-based engagement and education, supported by local government role modelling, has been identified as a more suitable approach and will be tested in later stages of the RICES project.

1. Introduction

Adequate, safe and reliable supply of water and energy is intimately linked to Indigenous health and social well-being (Mohtar and Lawford, 2016; Burgess et al., 2005; Garnett et al., 2009). There is a poor understanding, however of the barriers and opportunities toward improving essential service provision for Indigenous communities such as the First Peoples in North America and Aboriginal and Torres Strait Island people in Australia (Barber and Jackson, 2017; Santo Domingo et al., 2016; Garnett et al., 2009; Bailie and Wayte, 2006).

In Australia, over half of Indigenous Australians live in outer regional and remote communities both on the mainland and on coastal islands (ABS, 2016). A vast majority of these non-urban communities are located in deserts or tropical climates, requiring higher water and energy consumption and greater maintenance requirements for infrastructure (Beal et al., 2014; Ross et al., 2014; Yuen et al., 2001). Water supply choice in these regions is typically seasonally unreliable leading to a restricted daily water supply (e.g. water may be turned off several times a day), however many Indigenous communities have very high (>700 litres) *per capita* water consumption (Beal et al., 2016, 2014; Yuen, 2005; Pearce et al., 2007). Furthermore, energy intensive water supply systems are usually used to supply their community needs, for example many Torres Strait Island communities rely on energy intensive desalinated water systems which are powered by diesel generators (Richards and Schäfer, 2013). This reliance on high energy systems, combined with typically high water use, is putting increasingly significant economic and environmental pressure on these low socio-economic communities as well as local, state and federal service agencies.

A significant challenge for supplying water and energy to remote and isolated communities is the necessary subsidies from state government for covering the shortfall between the cost and revenue for providing these services. Given that there are hundreds of off-grid communities relying on diesel powered water supply in

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Australia, the focus on water demand management as a tool to improve water and energy use efficiencies in Indigenous communities is warranted and would greatly assist in reducing the shortfall between cost and revenue to supply these essential services.

This article presents findings from the Remote and Isolated Communities Essential Service (RICES) project recently undertaken in northern Australia. The RICES project is a three year research effort aimed at gathering baseline evidence and subsequently identifying sustainable strategies to reduce energy and water consumption in remote Aboriginal and Torres Strait Island communities. Fig. 1 presents a high level representation of the objectives and methods for each stage of the RICES project. See Beal et al. (2016) for more detailed information on the RICES project. Stage 1 of the research has been completed where 52 households in three remote Aboriginal and Torres Strait Island communities in Queensland and Northern Territory were monitored for water (total and hot water) and energy (total and hot water system).

Although the RICES project examines both water and energy demand, this paper's scope is focussed on the baseline water consumption patterns and identifying the end-use drivers of water consumption. This baseline information will refine the objectives of the two subsequent stages of the RICES project (see Fig. 1). Future publications will focus on the methods and results pertaining to stages 2 and 3 of the RICES project, which have recently commenced. The aim of this paper is to present and analyse results from the Stage 1 water use component of the RICES project; that is (i) present the baseline water consumption profiles for the remote communities in the study, (ii) identify high water end-uses and their drivers, and (iii) determine key considerations for a participatory-based water demand management approach based on insights from (i) and (ii).

This article will firstly provide an overview of previous studies of water use patterns and drivers in remote Indigenous communities before describing the methods used to measure and determine water use patterns, behaviours and activities in the participating communities in Section 3. The results, along with a general discussion will be presented in Section 4. Section 5 will then identify the main drivers of high water use and provide a discussion on the roles of local government and community in managing this demand. The paper will conclude with the overall implications of the research findings on the second Stage of the RICES research (developing and implementing a participatory-based demand management strategy in remote Indigenous communities).

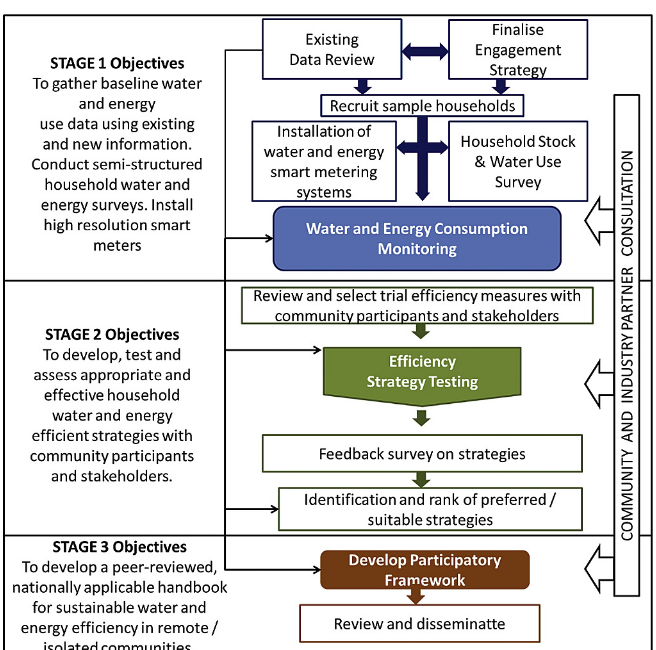

Fig. 1. Overview of objectives and methods for the RICES project.

2. Water consumption in remote Australian communities

While there is a reasonably good depth of literature on Australian Indigenous water rights (Tan and Jackson, 2013; Jackson and Altman, 2009; Toussaint et al., 2005) and Indigenous engagement in water planning and policy (Jackson et al., 2012; Willis et al., 2008) there is less understanding on actual residential water consumption patterns, activities and drivers. There is agreement between researchers that have explored this topic that water use is typically high and water literacy amongst Aboriginal and Torres Strait Island people (from a western, built environment perspective) is low (Beal et al., 2014; Ross et al., 2014; Pearce et al., 2007).

In their assessment of willingness to pay for water in five South Australian Aboriginal communities, Pearce et al. (2007) reported a range of estimated water use data ranging from around 450 to over 830 litres per person per day (L/p/d). They also recounted a common observation among local community attitudes toward water wastage, where children (being wasteful) and leaking pipes were considered the main contributors to high water use. Using a combination of modelling, interviews and metering, Yuen (2005) identified some common cultural themes and technical drivers that characterised water use in remote Indigenous communities. Similarly, Ross et al. (2014) used a mixed methodology of meters and interviews to measure and assess the pattern of water use in a Northern Territory community where ageing infrastructure and poor maintenance were found to be key drivers of high water demand. Using high resolution smart meters, household stock surveys and face to face engagement, Beal et al. (2014) highlighted the disproportionately large volume of outdoor water used in a remote Aboriginal community in far north Queensland. In 2016, Beal et al. using smart-meter enabled, empirically-based modelling techniques, demonstrated that an average reduction of 35% in water demand was achievable and can translate to a savings of around 47 kL of diesel per year, leading to a monetary savings of up to $AUD 20,000 per year for diesel and operating costs on only one island community alone.

Despite these previous studies mentioned, more knowledge of the detailed water and energy end-use demand patterns of residents is required to fully understand the drivers behind water use behaviours and attitudes and hence manage those drivers more strategically. This knowledge gap, including the need for more in-depth community-driven insights into water and energy attitudes and behaviours, has prompted the current research reported herein.

3. Methods

3.1. The communities

3.1.1. Community selection and project offer

Three communities in northern Australia are participating in the RICES project and are located in Queensland (QLD) and the Northern Territory (NT) (Fig. 2.). The communities were selected based on a range of geographical, technical and social/cultural criteria. Firstly, the communities needed to be representative of the inherent economic, geographical and environmental

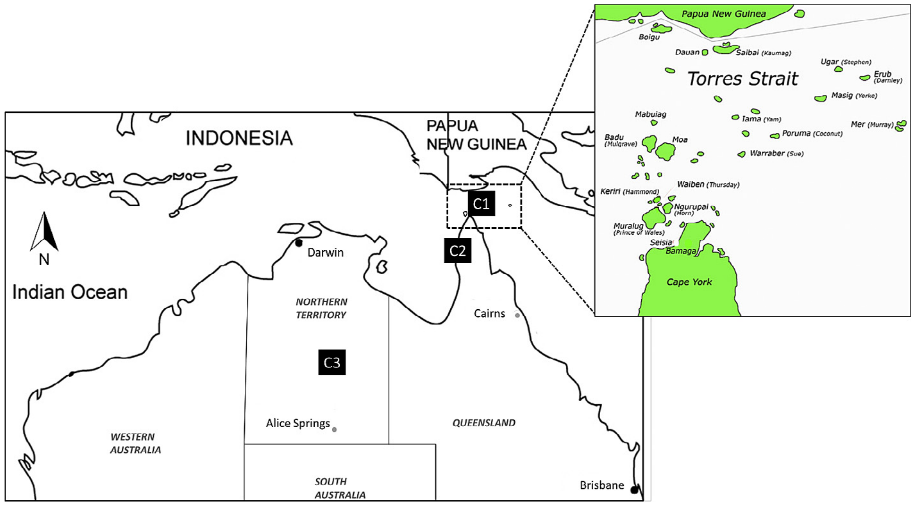

Fig. 2. Location of participating remote Indigenous communities in NT and QLD; Inset: Torres Strait Islands.

challenges of delivering reliable water and power supplies to remote and isolated towns. Secondly, the communities needed to have adequate and reliable telecommunication capabilities in order for the digital meters and loggers to remotely transfer large volumes of data efficiently and securely. Thirdly, and perhaps most importantly, there needed to be a strong existing platform of mutual trust and understanding between the community members and the project industry partners (including Traditional Owners, local council and community representatives) in order for the research team to further develop relationships and in-depth community engagement during the life of the project. Following early communication and project offer discussions with the key community members, councils and stakeholders in several communities in QLD and NT, three towns were selected based on the early indications of interest and seeing mutual benefit in participating. The project methods; including participant recruitment, survey methodology and implementation, and data generation, storage and management, were reviewed by the Griffith University Indigenous Research Unit and cleared by the Human Ethics office (GU Ref No: ENG/15/14/HREC). As part of this ethics approval, each community will remain unidentified.

3.1.2. Overview of communities

The key characteristics for each of the communities are provided in Table 1. Community 1 (C1) is a tropical island community located in the Torres Strait Island group in the Coral Sea, Far North QLD (Fig. 2 inset). Community 2 (C2) is a remote, off-grid tropical coastal town on mainland Qld and Community 3 (C3) is situated in the Central Australian arid (desert) zone.

Data on the number of participating households for each community are also presented in Table 1. Overall, given the acknowledged challenges inherent in recruiting remote and isolated Aboriginal and Torres Strait Island households (Jamieson et al., 2012; Jones et al., 2008), and due to the small populations, the participating household sample size was statistically solid, representing between 17 and 38% of total Aboriginal and/or Torres Strait Island households in each community (Table 1). In terms of family composition, age, gender balance, and household stock, the participating households were generally representative of each community when comparing numbers from previous studies of Aboriginal and Torres Strait Island households (Beal et al., 2014; Ross et al., 2014; Yuen, 2005).

3.1.3. Household recruitment process

Options for recruiting participants was firstly discussed with the council representatives, Indigenous Liaison Officers (ILO), Elders, Prescribed Bodies Corporate (PBC) and community representatives. The recruitment approach differed for each community based on the advice received during the initial site visit for each community. In C1, the research team were initially invited to attend a community workshop which included a short talk by the RICES team leader to the workshop participants about the RICES project. Further recruitment occurred during the follow up visit a month later where word of mouth, council encouragement and opportunistic recruitment secured 23 households. For C2, the recruitment was initially carried out largely by officers within the Aboriginal Shire Council and subsequent visits sought to confirm the participant's willingness through door to door introductions. For C3, door to door verbal invitations occurred during the first visit with the team being assisted by the local ILO and industry partner essential services officer.

3.2. Water use measurement and end-use analysis

Previous research has shown the high value of using a socio-technical (mixed method) approach to understanding the patterns and drivers of water and energy consumption (March et al., 2017; Liu et al., 2016; Britton et al., 2013; Gato-Trinidad et al., 2011) including, although to a lesser extent, in Aboriginal and Torres Strait Island households (Ross et al., 2014; Beal et al., 2014; Yuen, 2005). Therefore, a triangulated approach was used in the RICES project to build up a profile of water (and energy) consumption in each community. Firstly, desktop analysis was undertaken using existing data from the service provider and/or local authority. Secondly, digital smart meters and data loggers were deployed at individual residential properties to gain a higher resolution understanding of water demand. Thirdly, qualitative data from the household water and end-use surveys provided insights of the range of water (and energy use) behaviours, attitudes and habits of the residents.

3.2.1. Household water use measurement

Residential-scale water consumption was monitored using state of the art, high resolution digital water meters and logging equipment which were installed at all the participating households. The configuration of the meters is shown in Fig. 3, where the mains pipe

Table 1
Summary of population, water and energy supply characteristics for project communities.

	C1	C2	C3	Comments/sources
Population profile				
Population	254	269	444	From ABS (2016).
Approx. no. of households	58	71	70	C1 and C2 have a new housing project that will see a 10–25% increase, respectively.
RICES Project				
- Households[a]	22 (38%)	17 (24%)	12 (17%)	From participant surveys.
- Adults	72	38	39	
- Children[b]	49	20	20	
Average household occupancy[c]	5.8	3.4	5.8	
Governance arrangements				
Local government	Indigenous regional council	Indigenous shire council	Non-indigenous regional council	The only council based within community is in C2
Other organisations	Federal regional authority, Prescribed Bodies Corporate	Prescribed Bodies Corporate,	Local authority committee, Central Land Council	There are various Elder, men's women's, health, arts and sporting groups within each community.
Water supply and treatment				
Desalination plant	Y	N	N	
Surface water supply	Y – seasonal only	N	N	C1 supplements original surface water supply with desalination plant throughout the year.
Water treatment	Desalination and chlorination	Sand filters and chlorination	Advanced filtration and chlorination	C3 has a new treatment system due to poor quality groundwater.
Access to supply	Intermittent	Continuous	Continuous	C1 limited to 9 h a day during dry season week days.
Wastewater treatment	Biological aeration and UV disinfection	On-site septic systems	Anaerobic settling ponds	C1 has a new treatment system after septic systems were thought to contaminate aquifer.
Water rates	Non-residential only	Non-residential only	Non-residential only	All communities do not pay for residential water consumption.

[a] In parentheses is the percentage (%) of total Aboriginal and Torres Strait Island households in community.
[b] Children are categorised as <18 years old at the time of the survey.
[c] At the time of survey but liable to change throughout the year.

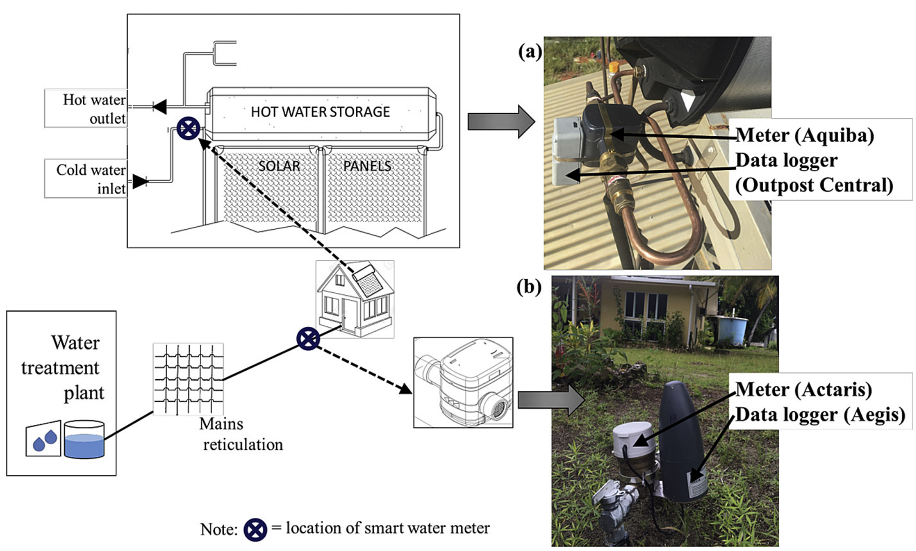

Fig. 3. Water smart metering configuration for participating households showing digital meters at (a) cold water inlet of SHWS and (b) mains meter at front of property.

(all participating homes) and cold water inlet of the solar hot water system (a small subset of participating homes) were metered. Existing standard council residential water meters were directly substituted with either Aquiba water meters (C2 and C3) or modified Actaris CTS-5 water meters (C1). These 'smart' meters measure flow to a resolution of 72 pulses/L or a pulse every 0.014 L. The smart meters were connected to Outpost Central WASP (C2 and C3) or Aegis RX (C1) data loggers programmed to record pulse counts at 10 s intervals. Data was wirelessly transferred to a central computer and stored in a database for subsequent analysis. A total of 50 water meters have been installed across the three communities: 20 in C1, 17 in C2 and 12 in C3.

3.2.2. *Household water end-use disaggregation*

To obtain individual water end-uses, the *Autoflow* software programme was used (Nguyen et al., 2015) which applies pattern matching algorithms and sophisticated data mining techniques on the high resolution dataset to reveal disaggregated water end-uses (e.g. shower, clothes washer, tap, leaks, outdoor, bath, toilet and dishwasher). This software uses the concepts based on other flow trace characterisation software (e.g. Mayer and DeOreo, 1999) but has increased capabilities using pattern recognition (i.e. Hidden Markov Model algorithms) coupled with other data mining techniques (i.e. event probability analysis) to automate the end use analysis process (Nguyen et al., 2015).

Using the high resolution datasets from the participating households, a representative sample of received data was extracted from the database and disaggregated into all end use events using the flow trace software *Autoflow*. Concomitantly with meter and logger installation, a water fixture/appliance stock survey was conducted at each participating home which facilitated the disaggregation of trace flows from each home and also provided a valuable snapshot of the daily water consumption habits within each home. Further discussion on this mixed method approach is presented in Beal and Stewart (2014).

3.2.3. Accounting for differences in community access to mains water

During the period of monitored water consumption, C2 and C3 had unlimited access to their mains water supply. For C1 however, there was a restriction regime in place where on weekdays residents only had access to water for 9 h a day and on weekends for 16 h a day. The chief reason for these restrictions to mains water access was to manage demand due to the extreme seasonal scarcity of water in the dry season. During these restriction times, residents still have access to rainwater (if available) from their individual tanks which are used for kitchen tap supply. In some cases, modifications to the original rainwater tank configuration have redirected mains water into a rainwater tank prior to entry into the house. This allows for storage of mains water and subsequent access to this stored mains supply during water during restriction times. This “24/7” water, as it is termed throughout the Torres Strait region, is desired by all but only a small percentage have this set up, and they go largely under the radar of the local authority. Having a limitation on water accessibility in C1 means that it is difficult to accurately compare water consumption across the communities without adjusting the C1 data to reflect demand (litres) versus available water (hours per day). To add further complexity, there was likely to be have been some atypically high water consumption activity during the times of access as people seek to take full advantage of the water availability. Therefore two water use datasets (“C1” and “C1 adjusted”) for C1 end-use disaggregation have been presented in the results section to provide a comparative range of average demand from C1 (restricted mains supply) and C2 and C3 (continuous mains supply).

3.3. Household water use survey

An essential component of the research approach is obtaining qualitative data through face to face engagement with the participants and wider community. During the baseline data gathering stage, the household water use survey was implemented via structured interviews to enable deeper insights into the behaviours, attitudes, concerns and challenges that the local community face with respect to their water and energy supply and demand.

The surveys were delivered in an informal interview format and consisted of 43 multi-item questions (totalling 78 items) which were designed to elicit information from participants about various aspects of household water, as well as standard demographic data. The majority of questions used categorical multi-choice, with some 5-point Likert Scales, and open-ended questions also included. Pictures were frequently used to support the questions, particularly the planned metering installation setup, the types of water and energy appliances in the home, and outdoor watering devices. Participants were asked questions about water and energy use behaviours both indoors and outdoors, along with the stock audit quantification and descriptions. They were also asked about their attitudes towards water quality (taste, smell etc.). Other variables included self-identification as a concerned citizen on household and community water supply security and self-reported identification of high water uses for their household. All survey responses were collated in a database along with the disaggregated water end-use data. The final database provided a comprehensive repository of water end-use data and matching socio-demographic data and responses to water consumption and efficiency behaviours. This is the first known study of its type to measure, at high resolution, such a range of variables for Aboriginal and Torres Strait Island communities.

4. Results and discussion

4.1. Household water use survey

4.1.1. Socio-demographic overview

A total of 52 households completed the survey between March 2015 and June 2016. The research team were accompanied by a local Indigenous council officer, ILO, or industry partner who was familiar with the community (e.g. NT Power and Water demand management officer). While all survey respondents spoke English, it was not always their first language and care was taken to ensure that all questions were understood by the householder by using non-verbal as well as verbal communication.

There was an equal representation of respondents who identified as Aboriginal heritage or Torres Strait Island heritage with 10 further respondents identifying as both Aboriginal and Torres Strait Island background. Only one participating household identified as non-Aboriginal or Torres Strait Island. It is widely acknowledged that many remote Indigenous households support extended families and have a frequently transient occupancy (Torzillo et al., 2008; Pearce et al., 2007; Yuen et al., 2001). This was indeed observed in all project communities where a broad permanent household occupancy distribution (Fig. 4a) and consistent visitor activity was noted from the survey.

The relative frequencies of household occupancy for the total RICES sample is compared with the overall QLD relative frequencies in Fig. 4b. This data demonstrates a substantially higher number of larger-sized households for the Aboriginal and Torres Strait Island communities which will impact on household water use patterns (although can also translate into lower *per capita* usage owing to the economies of scale). A transient occupancy rate can also influence the water demand profile of households throughout the year and this is especially relevant when developing a community education approach that relies on an assumed level of knowledge and engagement from all household occupants. Thus, some level of reengagement/education through regular and ongoing prompts needs to be integrated into any long-term water efficiency strategy.

4.1.2. Household water use stock summary

Household water use stock refers to all fixtures and appliances inside and outside the house that draws water from the mains water supply, along with rainwater tanks that may or may not be connected to the mains water supply (or to inside water use stock). There was variable penetration of water efficient fixtures in the homes with around 94% homes using dual flush toilets and over 40% of homes using new (3 years old or less) clothes washing machines (CW). Also, over 70% of homes used front loading CW which is typically associated with lower water demand during washing cycles (Carragher et al., 2012). Water efficient showers however, were less common with only 20% installed in the participating households. A range of photographs showing different shower heads were presented to the respondent during the survey and the older, standard shower head (typically >20 L/min) was frequently selected.

Rainwater tanks were common on C1 properties but not in C2 or C3. Similar to urban communities (Gurung et al., 2015)

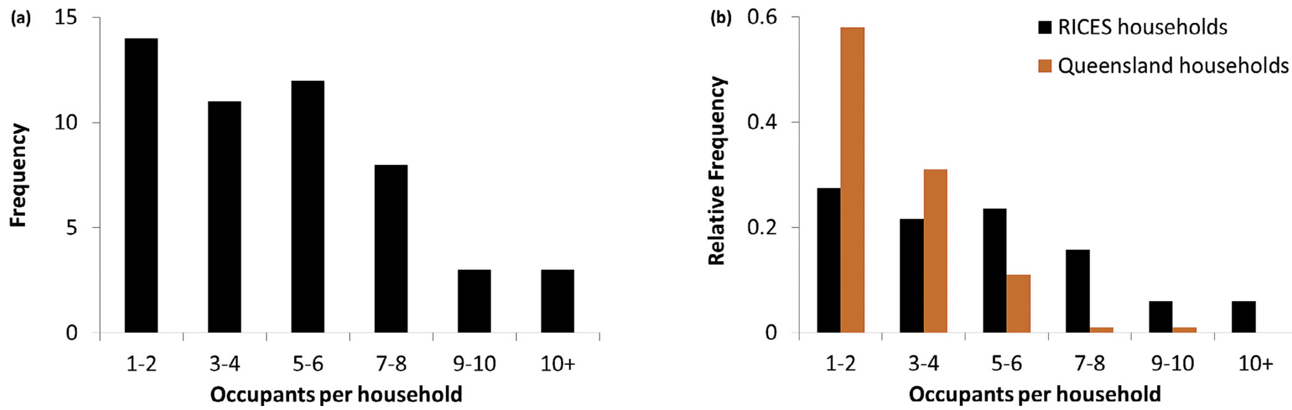

Fig. 4. Household occupancy distributions showing (a) frequency histogram of total RICES sample household occupancy and (b) comparison of relative frequencies with QLD average (ABS, 2016).

the operational and health risks associated with drinking rainwater tank supplied water were not always fully understood by council (or participants) and thus there was an ambiguous attitude to the value and importance of installing tanks in new properties, despite the acknowledged issues with water supply security and/or excessive outdoor water consumption by householders.

4.1.3. Leak reporting and response rates

Respondents were asked about their observations of leaks from toilets, taps, showers and outdoor taps and hoses. Although there would likely to be some social desirability bias and under-reporting in the responses (Fielding et al., 2012), over a third of all homes reported having outdoor tap leaks and 22% of householders reported leaky toilets and showers, respectively. There was a number of leaking outdoor fixtures observed in all communities, often severe and prolonged (e.g. observed in same locations across several visits). Leaking and poorly functioning stock is a common observation in remote community households (Ross et al., 2014; Torzillo et al., 2008; Pearce et al., 2007; Bailie et al., 2004) and associated with this is the underreporting, or poor response to the reporting, of leaks and maintenance issues in households (Torzillo et al., 2008). When asked about whether participants reported known leaks, a majority (94%) said “yes” (Fig. 5a). When further prompted as to whether they were happy about how long the reporting body took to respond to the leak issue, the responses were mixed, with a majority either unhappy (41%) or didn't know (15%) (Fig. 5b). The reporting body was typically the housing officer (for C1), council (for C2) or housing maintenance contractor (for C3).

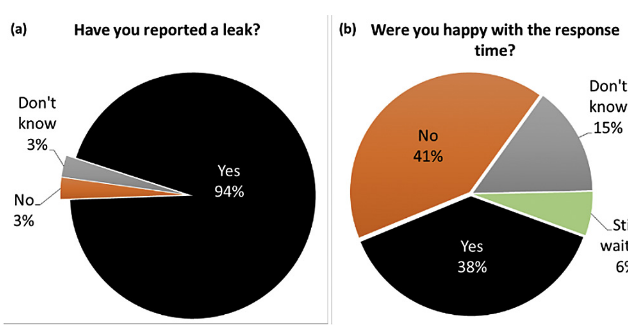

Fig. 5. Combined responses from all participants when asked about (a) leak reporting and (b) their satisfaction with the response time following a leak report.

4.2. Water consumption

4.2.1. Community water consumption

Accessing data to build up a community profile picture of water flows was very difficult (with the exception of C3), due to the incomplete data records that are often inherent for very small communities where staff, data monitoring and recording resources are limited. Notwithstanding this, high level information on water demand from residential, non-residential and non-revenue water (NRW) were estimated for each community (Fig. 6). The estimations indicate water supplied to residential buildings was high in all communities; ranging between 60 and 80% of total water supply (Fig. 6). In the Far North QLD communities, C1 supplied approximately 32 ML for the 2016-17 year, while total supply for C2 was 182 ML (2015–16). For the central Australian community, around 151 ML was supplied for 2015–2016.

The high proportion of residential water use in all communities is consistent with many Australian remote communities (White, 2017) where the number of occupants per household is considerably higher than in urban settings, and the proportion of residential buildings typically exceeds non-residential buildings. Water supply to non-residential buildings included council offices and grounds/parks, workshops and facilities, schools, health centres and service buildings (shops police, churches and fire-fighting).

4.2.2. Household total consumption

Total average household water consumption patterns for each community is displayed in Fig. 7, where both average daily use and average use across the period of measurement is shown. Average total daily litres per person (L/p/d) varied markedly between communities at 296 L/p/d, 998 L/p/d and 343 L/p/d, for C1, C2 and C3, respectively. The equivalent daily household use (L/hh/d) ranged from, 1,058 L/hh/d and 3,552 L/hh/d and ,1883 L/hh/d for C1, C2 and C3, respectively across each of the periods of measurement. For a point of comparison, the equivalent usage rates for south east QLD (SEQ) around the same timeframe ranged from 163 to 207 L/p/d and average daily household use ranged from 484 to 701 L/hh/d (Seqwater, 2017).

4.2.3. Household water end-use consumption

The consecutive, two week periods chosen for end-use analysis are indicated in Fig. 8. The breakdown of water end-uses for participating households during these typically warm and dry periods are shown in Figs. 8 and 9. Total average daily water consumption for periods of end-use analyses averaged from around 1,539 L/hh/d in C1 to over 6,200 L/hh/d in C2 (Fig. 8a). Total daily

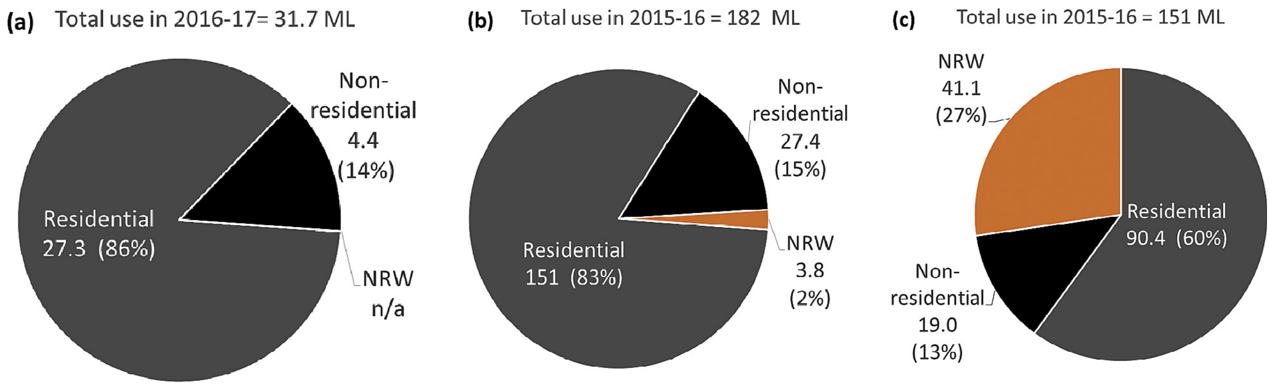

Fig. 6. Estimated breakdown of high level water end-use categories for (a) C1, (b) C2 and (c) C3.

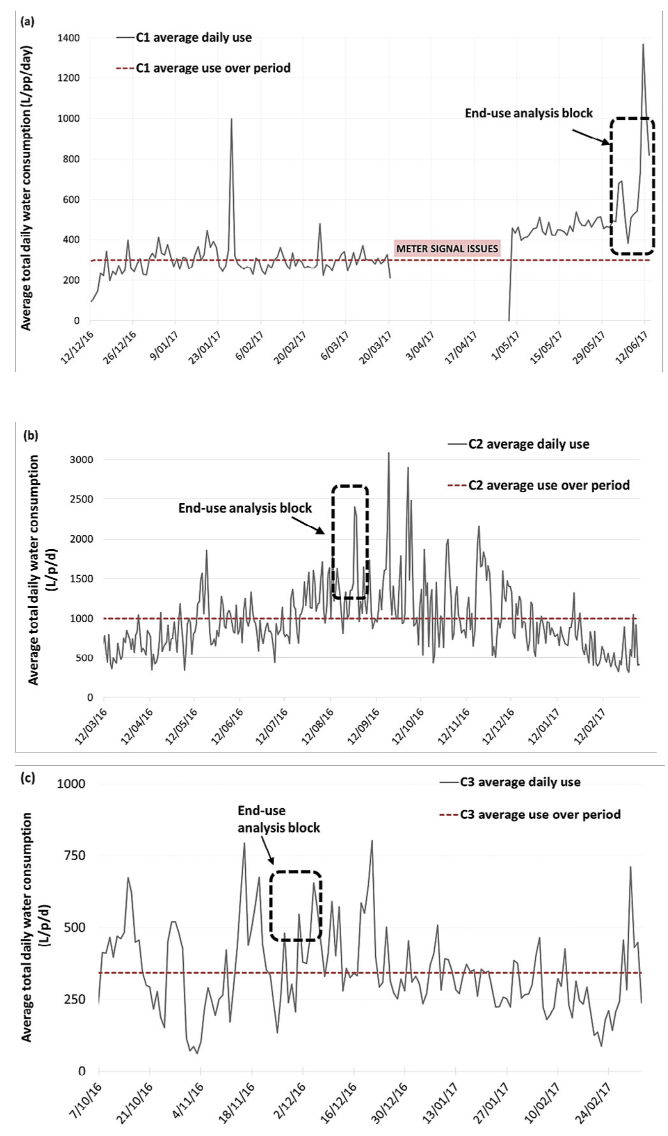

Fig. 7. Average total daily water consumption for (a) C1: 13/12/16 to 12/06/17, (b) C2: 18/2/16 to 8/3/17 and (d) C3: 5/10/16 to 8/3/17.

per person use averaged from 549 L/p/d to over 1,560 L/p/d (Fig. 8b). In most households, outdoor water use was the largest proportion of use, ranging from 62 to 86% of total average water use (Fig. 9). The other high water end-use identified was from leaks (Fig. 9) which confirmed the outcome from observations and discussions with participants, the wider community and council during site visits.

5. Drivers of high outdoor water use activities

From analyses of the survey responses, participant discussions, end-use disaggregation and council consultation it emerged that several key drivers were contributing to the observed high outdoor water use activities. Following baseline analysis, further discussions were held with all participants about their individual water end-use breakdown activities and to identify more accurately the drivers (i.e. reasons and motivations) behind their high outdoor water use. These drivers were verified and refined during follow up discussions with the participants, and then grouped into five main outdoor water use themes: 1) amenity, 2) health, 3) cleaning, 4) cooling and 5) social. These are presented in Table 2, along with a short description of the intended benefit of the outdoor water use activity. All of these activities were observed during community visits and captured from the survey data and discussions. The drivers of high outdoor water use that have been identified in this study are closely linked to necessary day to day functioning e.g. health (dust suppression, cleaning down outdoor surfaces, house and personal cooling), food preparation (fish and meat cleaning) and food gathering (washing down boats and hunting equipment) (Table 2).

In comparison, outdoor uses in an urban context are predominantly driven by more 'discretionary' or comfort/quality of life (e.g. lawn/garden irrigation, car washing, pool filling) (Beal and Stewart, 2011; Gato-Trinidad et al., 2011). The demand for these discretionary uses in urban settings are usually managed through pricing mechanisms where the user pays a variable consumption component for high usage, such as an inclining block tariff (Sahin et al., 2017). While there is a need to place a value on water as a natural (and often limited) resource, the usual economic approach of water pricing is not currently applicable to most Australian Aboriginal and Torres Strait Island communities. As Pearce et al. (2007) and Jackson and Altman (2009) have observed, Australian Indigenous people, in remote communities in particular, tend not to make a clear distinction between water as a natural and cultural resource, and the water readily available out of a household tap. Furthermore, some of the water use activities (e.g. dust control) presented in Table 2 could quite feasibly fall under the responsibility of local government service provision. The identified motivations for high water use presented in Table 2 thus raise two important questions relevant to the future design of an effective water demand management plan in

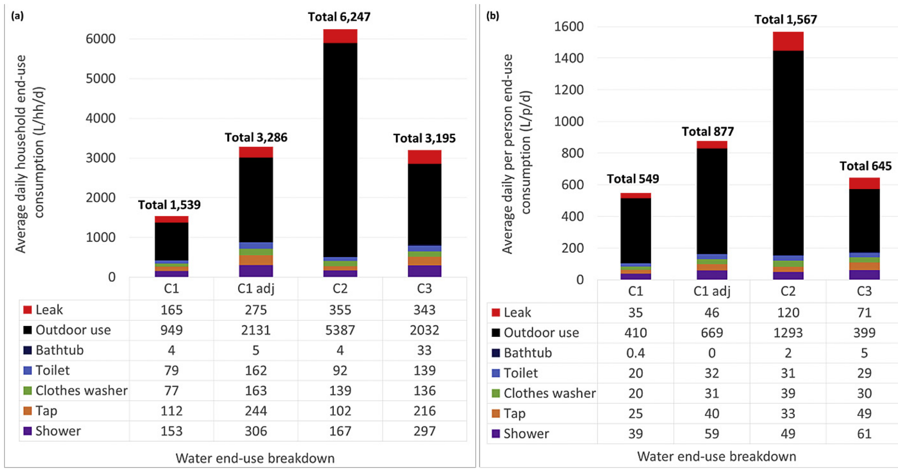

Fig. 8. Average total daily end-use for (a) household and (b) per person.

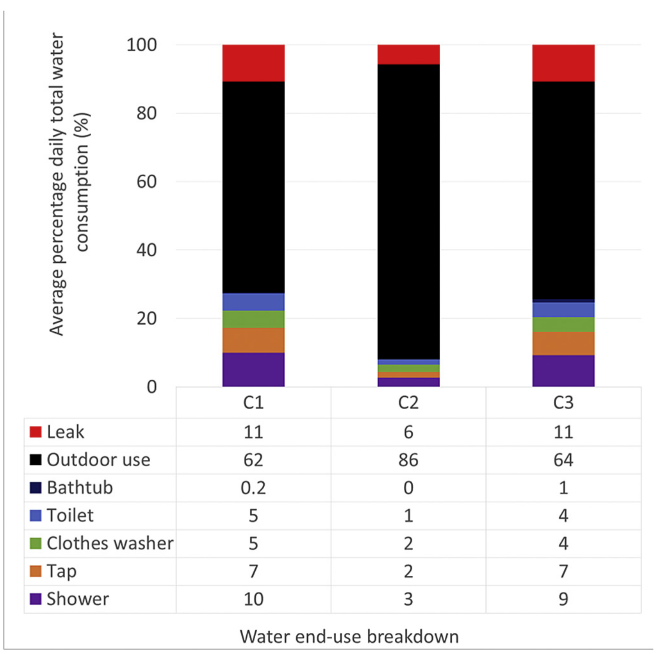

Fig. 9. Average percentage of daily total consumption.

remote communities: 1) what level of responsibility does the local government have in promoting water efficiency by maintaining a healthy community environment (e.g. road works to improve/reduce dust, fish cleaning amenities, maintaining green 'cooling' spaces), and 2) how best to encourage water efficient behaviours in remote community residents when water is not paid for, yet intricately linked to cultural and day-to-day life activities? Each of these questions will now be further deliberated below.

5.1. Role of local governments in reducing outdoor water demand

5.1.1. Improved service provision

In terms of the first question above, it could be argued that some of the drivers of high household outdoor water use are a result of the inefficiencies of local government service provision (e.g. dust control, greening). However, this can be problematic as remote local governments are frequently resource-strapped and do not always enter service provision arrangements with non-rate paying residents with the best of faith (Hunt, 2013; Sanders, 1995). Furthermore, decades long tensions between local authorities and Aboriginal land ownership are embedded within this dilemma of service provision to non-rate paying customers (Hunt, 2013; Jackson and Altman, 2009; Sanders, 1995). With the emergence of independent Indigenous remote local authorities in Australia, there has been improvement in the community relationships, and

Table 2
Key outdoor water use drivers and their intended benefit as identified from the HWEUS.

Driver	Intended benefit
Amenity	• Foster a green space for visual amenity and maintain social expectations • Watering plants and gardens to maintain vegetation and shade
Health	• Dust suppression by dampening bare earth to reduce airborne dust • Maintain healthy environment especially for young children and elderly
Cleaning/washing	• Clean fishing boats, tables & equipment • Wash down concrete or wooden verandahs and decks • Clean cars (dust build up is prevalent with the unsealed roads)
Ground cooling for heat relief	• Soaking the bare earth to cool earth and generate an evaporative cooling effect with the prevailing wind - especially important to provide a cool area during social gatherings
Social gatherings/ children's play	• Continual access to water for body cooling and a source of outdoor drinking water during social occasions including tombstone openings, sorry camps and general gatherings • Access to hose for water play and drinking for children during summer

the level and quality of service provision (Hunt, 2013; Sanders, 1995) There remains, however, limited capabilities of many local governments that do not have a rate base to generate their own revenue and maintain adequate service provision due to lack of community capacity to pay service charges: thus there continues to be shortfalls between community expectations and local government delivery, such as observed in the participating communities in this study. These shortfalls present a complex challenge especially as potable and non-potable uses are so intertwined with Aboriginal and Torres Strait Island culture.

Deeper discourse on the historical and current limitations of remote local governments to provide optimal essential service provision is beyond the scope of this paper, but nevertheless needs to be considered when designing a community driven demand management plan. As a (simplistic) example, in remote Indigenous communities in Australia, sealed roads are the exception not the norm but are a recognised primary source of air pollution, adding to negative environmental health outcomes prevalent in these communities (Bailie et al., 2004; Bailie and Wayte, 2006). In most Australian local government jurisdictions, the role of dust control would be a local government responsibility and would include sealing roads or maintaining adequate dust control via road watering and/or vegetating road sides and exposed earth. As stated before, however, many Indigenous local authorities, or local authorities that incorporate Indigenous communities, either do not have adequate resources or are not always fully committed to such service provision to non-rate paying customers. Thus devising a water demand management plan that relies on increased service provision as part of its strategy may not be a viable or successful option without careful consultation and deep understanding of the community-specific governance environment.

5.1.2. Enforcing water restrictions

Voluntary restrictions on outdoor watering times, or prohibiting such activities altogether, may not be a successful long-term option based on the consistently high water use monitored in the communities during periods where residents were notified to limit outdoor water use to certain times and days of the week. Ultimately, restricting or ceasing outdoor water use is voluntary and thus relies on the buy-in and close engagement from community (Dolnicar et al., 2012). As an example, when C1 household data is adjusted to compare equivalent water use per hours of available water (C1 adj) indoor demand becomes the highest of all three communities rather than the lowest (unadjusted) (Fig. 9). This suggests that the water use behaviours in households that are exposed to mandatory water conservation methods are similar to those households where there is little enforcement to reduce water use. For C2, all households were personally visited by council in July–August of 2016 and informed of the need to restrict their outdoor watering activities to early morning or later afternoon only. While there was a small reduction in total water consumption, outdoor use remained significantly higher than other end-uses. Even in C3, where water use was generally lower than the other communities and total consumption has seen a decline over the years, outdoor use remains substantial, despite previous pilot water conservation programs (e.g. Abrahams and Henderson, 2010). These observations further emphasise the need to understand the drivers of high outdoor water use, and the barriers to reducing such levels of water use from the householder's perspective, in order to establish long-term behaviour change toward outdoor use.

5.2. Role of community in water demand management

Creating sustained behaviour change is not a simple and short-term process in any community, particularly in remote settings that require strong cultural, historical, governance, geographical and environmental considerations. While this is a complex and sensitive challenge and despite the lack of financial motivation, there is a clear and important role for householders in reducing water demand, especially outdoor. Pearce et al. (2007) consulted five Aboriginal communities and found that while their willingness to pay for water was low, their attitudes to water conservation and efficient use varied and was likely to be more positive with increased consultation and engagement from local government. Pearce et al. (2007) suggested that non-monetary demand management strategies such as sharing the responsibility of water management with local residents may have at least the same, if not greater, conservation outcomes than introducing water tariffs. Russell and Fielding (2010) support the notion of using good communication and community involvement to encourage and enthuse local residents in improving water efficiency behaviours. In the absence of financial incentives, which are a well-recognised demand management tool, Russell and Fielding (2010) observe that having 'saving water' as a whole-of-community commitment is emerging as a strong motivator for water conservation. Although many studies around water conservation attitudes and behaviours have not included Indigenous households, much work has been done in the Australian Indigenous water rights, planning and allocation space (Jackson et al., 2012; Tan and Jackson, 2013; Touissaint et al., 2005). This can be drawn upon during development of participatory water efficiency processes, where identified cultural and spiritual water values and stories could help shape the narrative to motivate behaviour change. From a more technological and engineering perspective, there is less to draw on, though the empirical baseline data on residential water use presented herein will greatly strengthen a platform from which to objectively evaluate water demand reduction strategies.

6. Conclusions

Stage 1 of the RICES project has used smart metering-enabled data and social surveys to document water end-use patterns in participating Aboriginal and Torres Strait Island households. Outdoor water use ranged from over 1,500 to 5,300 L/household per day, representing up to 86% of total use. By identifying the main drivers for high outdoor water use: health, cooling, cleaning, social and amenity, a targeted demand management plan, underpinned by empirical data, will be developed as part of RICES Stage 2. Traditional monetary demand management methods or enforcing water restrictions are not likely to be relevant or successful in the long-term and the role of the local government in improving service provision to reduce high household water use activities (e.g. dust control) is not a simple matter. Demand management strategies most suited to the complex motivations that exist around high water use are likely to involve ongoing community engagement, education and consultation between residents, the local authority and other stakeholder groups. Encouraging family members to pledge a commitment to reducing water use that is based on feedback on their actual household consumption practices and is willingly entered into as part of a community supported initiative may be a strategy that will engage individuals toward reducing water use. Local council role modelling of water efficient practices such as using tap timers and prudent irrigation of council and public spaces will also promote community action and goodwill. Such approaches will be considered during the next stage of the RICES project when developing community-directed water efficiency strategies. Ultimately, these tested efficiency strategies will be rolled out in across other remote communities in Australia with similarly constrained water and energy supplies.

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