SMART METERING ENABLES EFFECTIVE DEMAND MANAGEMENT DESIGN

A case study to demonstrate that an early mixed-method baseline analysis is essential to designing robust, cost-effective demand management programs in remote communities

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ABSTRACT

The water demand and water use practices of each community are different. Designing cost-effective demand management programs requires investigating and responding directly to the unique water issues and opportunities of each community (Turner *et al.*, 2010).

As presented in this paper, a 'mixed-method baseline analysis' has proven to be valuable in developing a demand management program tailored to the distinctive community context. A mixed method baseline analysis is comprised of two interlinked components: (i) quantitative smart meter data analysis to create a detailed understanding of the water demand profile; and (ii) qualitative social research to understand the social, cultural and institutional influences that drive existing water patterns.

This paper shares the mixed-method baseline analysis and resulting implications for a demand management program implemented in the remote Indigenous community of Gunbalanya, Northern Territory, in 2013. This paper is one of the first case studies to document how smart meters, as part of a mixed-method baseline analysis, can target demand programs in remote communities more cost-effectively, by enabling scarce program funds to be focused on areas of highest need and greatest impact.

The smart meter component of the baseline analysis revealed leaks to be the greatest opportunity for demand reduction in the community, rather than the previous focus on consumption and household behaviours. The social research revealed a range of social and cultural considerations around leaks in the community, which were important to respond to in the program design. The demand management program design was adjusted to enable a more accurate response to the specific water issues and opportunities uncovered by the mixed-method baseline analysis.

The principles of the mixed method baseline analysis can be applied to any region to develop robust, cost-effective, accurate and impactful demand management programs.

INTRODUCTION

Water service delivery in remote communities

Indigenous Essential Services (IES) Pty Ltd, a not-for-profit subsidiary of Power and Water Corporation, provides water services to 72 serviced remote

Aerial view of Gunbalanya, with the Arnhem Land escarpment beyond (K Ross, April 2014).

Indigenous communities and 66 smaller 'homeland' settlements peppered across the Territory. IES and its predecessors have provided electricity, water and sewerage services to Indigenous communities in the Northern Territory since 1987 (PWC, 2013).

Water service delivery in the 72 remote communities involves unique challenges, including the small size of service locations, ageing infrastructure of variable standards and high-energy costs associated with the provision of water services (PWC, 2009).

Remote communities also have a unique context for the design and delivery of demand management programs. Residential meters are not the norm, therefore demand management programs are often designed on bulk meter data analysis and lessons learned in other contexts. In the Northern Territory there is no water pricing for residents in public housing. Other important considerations are the need for and implications of cross-cultural communication and mutual understanding as well as the relative economic disadvantage of the Indigenous community (PWC, 2009).

Smart meters in remote communities

Smart meters differ from normal, mechanical meters in that they can digitally display flow rates in real time, usually remotely. Smart meters and smart meter data have been increasingly used in Australia in water service delivery since 2008 (Giurco *et al.*, 2008b). The demonstrated benefit in urban areas has been improved water management through distribution and customer leak detection, tailored demand management programs and policies, evidence-based customer education, and program evaluation (Giurco *et al.*, 2008a; Giurco *et al.*, 2010; Mead and Aravinthan, 2009). Recently, a novel mixed-method approach was used to reconcile differences between perceived and actual residential end-use water consumption in urban areas (Beal *et al.*, 2011).

To our knowledge this case study is the first documented program in Australia that has used a mixed method baseline analysis (smart meters in conjunction with social research) to design, monitor and evaluate a demand management program in a remote Indigenous community.

This case study has many components to discuss, including the benefits of smart meters for program design, program and water demand monitoring, program and action evaluation, stakeholder coordination and efficiency gains, and the overall cost effectiveness of smart meters in remote communities. The authors plan to present these aspects in various papers. This paper focuses on the benefits of a mixed-method baseline analysis in the design stage in order to develop robust demand management projects.

Site of the demand management project: Gunbalanya

Gunbalanya, an Indigenous community in western Arnhem Land, Northern Territory (NT), is experiencing increasing water scarcity and rising water demand. The town's water is obtained from a shallow, sandy soil aquifer that depends on seasonal recharge. Its unique characteristics prohibit higher extraction rates, which means the community is at a high risk of water shortages at the end of most dry seasons. This water scarcity, coupled with increasing demand, triggered the development of a water demand management program led by Power and Water Corporation in 2013 that sought to involve the Gunbalanya community and key stakeholders to be water-wise (PWC, 2012).

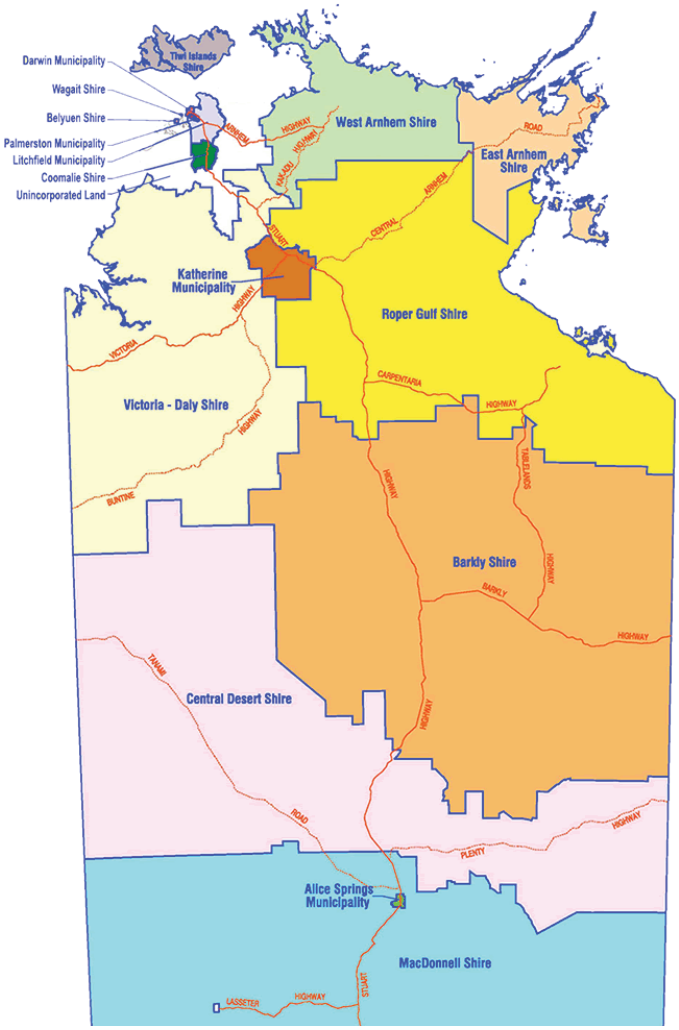
Gunbalanya (Oenpelli) is located approximately 300km east of Darwin, within the West Arnhem Regional Council (WARC) area. Situated in the dry tropics region, Gunbalanya is characterised by two hot tropical seasons: the dry (April–September) and the wet (October–March). The town is surrounded by floodplains that are inundated during wet seasons. As such, the main access road is usually impassable during the wet season and the community is accessed via an airstrip.

The most recent census estimates Gunbalanya's population as 1,371 (ABS, 2011), but other estimates vary from 1,500 to 3,400 (NTG, 2014a; NTG, 2014b). Territory and national development initiatives suggest that further housing could be developed over the next five to 10 years (Australian Government, 2011; 2013), leading to increased population and water demand to an already stressed water source.

Water provision and metering in Gunbalanya

IES has been working since at least 2003 to address water scarcity concerns in Gunbalanya.

The majority of the 268 serviced water connections in Gunbalanya are public housing. The NT Department of Housing owns and leases 163 public homes to Indigenous residents, while 94 are commercial and government buildings.



Gunbalanya is located in West Arnhem Shire, at the top of the Northern Territory (NT Dept of Local Government and Regions).

Gunbalanya has an estimated population around 1,500, with 268 serviced water connections (Google Maps).

Only commercial and government premises are charged for water in remote communities under current NT policy, and as such have a quarterly water meter reading and billing cycle. All other lots were metered in 2003 to assist with measuring demand due to rising water scarcity issues. However, major challenges to reading all meters and maintaining them in reliable service in remote areas meant that the data was of only limited value in appropriately assessing the demand profile of the community.

Previous bulk meter data analysis indicated that generally around 80% of water in the community is used in households, and only 20% of water is used in non-residential facilities (such as the school, clinic and the store) (PWC, 2012). System losses could not be easily estimated. Public housing consumption levels based on bulk data were coarsely estimated to be of the order of 1000 L/c/d (with poor confidence rating of the data) (PWC, 2007).

Initial demand management program design for Gunbalanya

Based on the initial high-level bulk water analysis, which indicated high average consumption levels in public housing, the draft plan was to focus primarily on engagement with the public housing tenants and housing maintenance agencies and to use smart meter data to aim the program at the largest users.

In 2012, Power and Water received funding from the Federal Government to implement the demand management program. Power and Water installed smart meters between June and October 2012, and developed the "Community Action Plan: Water Efficiency in Gunbalanya Households" in a collaborative partnership with Gunbalanya community leaders and Project Partners (including NT Department of Housing, the West Arnhem Regional Council (WARC), and the NT Department of Community Services) in November 2012. Power and Water coordinated the partnership with these stakeholders to explore how smart meters would benefit the aims of all partners and how collaborative action on the smart meter analysis would improve the actions to decrease water demand.

This draft community action plan proposed technical and social demand management components (PWC, 2012), including:

Social/Behavioural

- Water efficiency communication and marketing tools
- Indigenous water conservation officers/educators
- Household commitments to save water in the home
- Daily community water use target and tracker.

Technical/Appliances

- Outdoor water-efficient appliances for households
- Working with key maintenance agencies to respond to smart meter data analysis of high water use.

The installation of smart meters was a key feature of the program. Power and Water recognised the limitations with using bulk meter data to, firstly, understand the community's water use patterns and, secondly, to plan appropriate responses. Therefore, one of Power and Water's goals for this innovative project was to use the analytical power of smart meter data to refine the program design, direct and monitor program action, and evaluate the program. Power and Water sought a mixed-method approach to both refine the program design and evaluate the program, recognising the value of integrating the technical and social aspects.

ISF was engaged by Power and Water to provide design recommendations, monitor smart meter data during implementation and evaluate the effectiveness of the program. To inform the design recommendations, ISF undertook a mixed-method baseline analysis within the community in April 2013, to explore and understand the demand patterns. This paper presents the findings from the mixed-method baseline analysis and describes how the findings influenced the program design. This case study demonstrates the value of a baseline analysis that provides a granular understanding of the water demand, and the reasons behind the water use patterns, for developing appropriate and well-targeted demand managed programs. The lessons from this baseline analysis provide transferrable lessons for designing demand management programs in this context.

APPROACH

ISF used a mixed-method approach to undertake the baseline analysis, drawing on both quantitative and qualitative data sources. The quantitative method analysed smart meter data to provide a detailed breakdown of water demand patterns within the community, while the qualitative social research, including community surveys and stakeholder interviews, provided insights into water demand patterns.

First ISF analysed smart meter data to identify: (i) the different types of

water demand; (ii) customer lots with excessive demand; and (iii) the largest opportunities for savings. Smart meter data from 257 properties was analysed. For this baseline analysis, water demand was divided into three categories:

1. Legitimate consumption (i.e. actual customer usage; defined in the data by usage stopping and starting over periods < 24 hours);
2. Intermittent leaks (i.e. behaviourally based leaks such as sprinklers left on, or hardware leaks such as toilet flushes that stick; defined in the data by consistent demand that lasts between 24 and 48 hours); and
3. Continuous leaks (i.e. longer-term behaviourally-based or hardware leaks; defined in the data by demand lasting longer than 48 hours).

To analyse the smart meter data, ISF developed custom scripts that separated water demand into these three categories across all lots. Initially, only three months of complete smart meter data was available for analysis. The analysis also calculated basic statistics including the mean, median rates of increase and the relative comparisons between water use types. For the purposes of this study, the suite of scripts analysed the smart meter data at two levels: the community as a whole (all 257 connections), as well as comparing public housing (163) and all other properties (94).

Next, social research was conducted to gain insights into the influences that drive the identified water demand patterns. Results of the smart meter data analysis informed the interview and survey question design. Interviews were conducted with four groups: Indigenous community leaders (2), local West Arnhem Regional Council (WARC), school, business and health clinic employees (4) and Project Partners, including representatives of WARC, the NT Department of Housing, NT Department of Community Services and Power and Water (8). Topics included the interviewee's role, goals, definition of success and perceptions of barriers in relation to the program. Brief surveys (12) and participatory mapping exercises with community members (25) focused on source, size, duration and impact of continuous leaks, with some investigation of outdoor water use and intermittent leaks.

RESULTS

Leak volumes

The mixed-method baseline analysis found leaks were a significant proportion of measured demand. The smart meter analysis suggested 20% of the measured consumer demand was lost in continuous leaks (Category 3 above). A further 14% was lost in intermittent leaks (Category 2). Stakeholder interviews reiterated perceptions around the 'significant' amount of leaks in public housing and their perceptions of the damage it causes to the assets, such as floor, wall, ceiling and electrical damage.

Factors contributing to leaks

The social research confirmed new homes had minimal leaks whereas every older home visited reported an existing or recent leak.

The research identified potential drivers of the high leak volumes. Local employees felt that the main sources of continuous leaks in the community were corroding taps (which was corroborated by the housing maintenance and repairs database). A maintenance employee suggested the need for stainless steel tap upgrades instead of outdoor water-efficient appliances, which he considered to be unsuited for the water pressure, pH and social context.

Stakeholders described the sources of intermittent leaks as extended periods of watering lawns, taps that were challenging to turn on and off (due to corroding materials) and observed consumer habits of leaving taps turned on.

All groups perceived the length of time between the start of the leak and its rectification as a reason for high leak volumes, due to barriers in identifying, reporting and responding to leaks.

Barriers to addressing leaks

The social research highlighted several barriers and drivers for addressing leaks in public housing. The community surveys highlighted concerns over financial or other negative consequences as a barrier to reporting. Stakeholders corroborated a perception that public housing tenants may feel uncomfortable reporting leaks and fear negative consequences, such as financial charges.

The surveys indicated that tenants were deterred from reporting leaks by the perceived length of time for the leak to be rectified. In addition, community members spoke of only certain household members having cultural authority to report the leak; therefore leaks may go unreported for a variety of reasons (i.e. availability and mobility of those with authority).

Community members described the main drivers for reporting leaks as concern for the health and safety of the children and frustration caused by the location of the leak, i.e. toilet leaking on the floor or large kitchen tap leaks. Both community surveys and stakeholder interviews confirmed that small leaks are tolerated and aren't usually reported independently.

Stakeholders perceived that water conservation is not a priority, nor well understood across the community, compared to broader community concerns.

Legitimate consumption

The mixed-method baseline analysis suggested low volumes of legitimate water consumption. The smart meter analysis indicated that half of public households consume relatively small volumes of water, less than 800L/d. Assuming an average of eight people per household, about half of the community members may consume less than 100 L per person per day. The local clinic reported high prevalence of skin disease, scabies and diarrhoea, which are associated with low water consumption. School staff also perceived low rates of washed clothes among children, and housing maintenance employees confirmed limited access to effective washing machines.

Social marketing and education

Interviews highlighted the perception that social marketing and community education materials need to be visual and show the relationship between aquifer levels and water outages. Community leaders felt visual communication was most effective in the community and suggested creating posters showing the aquifer levels during the wet and the dry season, and to relate the relationship of water levels to pressure (in this context lower aquifer levels means less water can be pumped and operators need to reduce the water available to the town, from the tank).

Distribution leaks

Community leaders and local employees perceived frequent instances of prolonged distribution leaks in the pipe network. The Power and Water representative in Gunbalanya reported difficulties in promptly addressing

distribution leaks because of the significant workload. These insights into leaks and consumption influenced the program design.

DISCUSSION OF PROGRAM DESIGN IMPLICATIONS

Enhanced focus on leaks identification and reporting

The quantitative volume and qualitative perceptions of leaks uncovered by the mixed-method baseline suggested that only a concerted effort to address the leaks throughout the entire water system would address the water scarcity concerns of this growing community. However, this demand program was focused on customers, therefore technical and social recommendations were developed to further tackle leak reduction on customer premises.

On the technical side, it was recommended that the budget be increased to fix common forms of leaks (such as corroded taps) and water waste (such as missing sink plugs) by decreasing the budget for outdoor water-efficient appliances. It was also recommended that smart meter analysis of the "top 10 leaks" be shared with Project Partners regularly to address and fix the major leaks.

On the social side, it was recommended that a collaborative community target of 'all leaks reported' replace the original community target of "x litres per person per day" (a specific target number had not yet been decided on in the draft action plan). Other social recommendations were to further refine messages delivered by the Indigenous water conservation officers to specifically address and build capacity of public housing tenants to help overcome barriers to leak reporting; for example, messaging that: explains the benefit of reporting leaks (e.g. improved pressure, decreased health risk); reassures community members they will not get into trouble or be charged as a result of reporting a leak; helps families recognise all types of leaks from small to large and plan who will report leaks.

Social marketing implications

Keeping community social marketing simple and clear while avoiding messages that relate to water consumption behaviours and health was a recommendation that emerged from the baseline analysis. The smart meter analysis of household water consumption directed the program away from educating on water-use behaviours.

The World Health Organisation defines 'sufficient water' use as between 50 and 100 L/p/d to ensure that most basic needs are met and few health concerns arise (WHO, 2003). The smart meter data suggests that about half of Gunbalanya residents are near the WHO guideline. This is not to say that the water isn't available, but rather that half the community members are using 'sufficient' volumes of water or less. The qualitative research suggested that the education or messages should not inadvertently encourage community members to prioritise water efficiency actions at the expense of health outcomes.

Therefore, it was recommended that all messages relating to shorter showering times, washing clothes or bedding with a full load (in alignment with guidance in the National Indigenous Housing Guideline, Australian Government, 2007), flushing toilets with a half or full flush as needed, and children playing under outdoor water taps are not included in the program.

A smaller number of targeted messages were recommended, including: (i) turn off taps and help others turn off taps; (ii) report leaks to Shire; (iii) use a sink plug; and (iv) explain that aquifer levels vary between the wet and dry season (to explain the reasons why these actions are important).

Gunbalanya at the end of the wet season (K Ross, April 2014).

Influence of baseline timing on program design

Timing constraints external to managers' control influenced the ability to refine several aspects of the program design. The program had to be pre-designed to get external funding and smart meters were included, but practicalities of delivering the whole project in 18 months meant aspects had to be delivered in tandem.

The project decision-making and rollout had to start before a detailed smart meter analysis could be undertaken. For example, Project Partners agreed on the distribution of outdoor water-efficient appliances to community housing (to test the resulting reduction in demand) before the smart meter analysis. While the smart meter and social analysis indicated that consumption was not the primary water use area that needed attention, and that investments should focus on rectifying leaks, the prior agreement meant that outdoor appliances remained as an investment for the program.

Additional insights were discovered as smart meter analysis grew more sophisticated during the project implementation. This subsequent analysis would have improved program design if timing had allowed smart meter analysis to be more thorough, earlier. For example, the subsequent research indicated that:

- Continuous and intermittent leaks in public housing were losing similar volumes for non-public housing properties, meaning per property losses are higher in other properties than in public housing. Non-residential leaks were addressed through ad hoc interventions by Power and Water to the highest users, which were also directed by the smart meter data analysis. Audits were performed as part of a related project to assess large customer consumption issues; however the smart meter analysis indicates this is an area for future expansion of the program.
- The smart meter analysis confirmed a correlation between the age of the housing stock and existence of maintenance leaks, which means demand management program components could be developed specifically to support the oldest housing stock.
- Distribution leak volumes were potentially equal to or greater than building leak volumes, which indicates opportunities to prioritise investigation of distribution leaks (available bulk data had significant error, so needs further investigation).

It is desirable to have two years of smart meter data to thoroughly analyse at the beginning of program design in order to feed into program development. However, the design recommendations coming out of three months of data still proved very useful in enabling a more robust program design for Gunbalanya.

Transferability to other communities

The mixed-method baseline approach is transferable to all community types and means that demand management funds can be targeted, cost-effective and successful. This method can be summarised in several important principles.

Firstly, design the demand management program based on a tailored and triangulated evidence base, drawing on the combined power of smart meter analysis and social research. It is also important to cross-reference multiple data sources to ensure that the opportunities for greatest cost-effective savings are discovered and addressed appropriately. For example, check and cross-reference the stories arising from the smart meter data analysis, community interviews, repair and maintenance employees and database, community leaders, etc.

Secondly, where possible (considering budget and other time constraints), allow for enough time to conduct a thorough and meaningful investigation before allocating funds to specific components of the demand management project. This ensures scope to allocate resources accordingly from the beginning, to the areas of greatest need identified in the baseline analysis.

Finally, the baseline analysis should be holistic and include a water balance of the entire system (Turner *et al.*, 2010). That is, when designing a water-reduction program in rural or remote communities, investigate all potential sources of water waste, including: supply infrastructure leaks, dwelling leaks and behavioural leaks.

CONCLUSION

The many variables that influence water demand are often complex and multi-layered. Hence, it is imperative to analyse the water context qualitatively and quantitatively to highlight the primary water issues and opportunities for demand management. To be successful and cost-effective, community demand management programs need to respond to their unique social, cultural and infrastructure issues.

This paper demonstrates that an early and thorough mixed-method baseline analysis (including both smart meter analysis and social research) is essential to designing robust, community-appropriate and cost-effective demand management programs in remote communities. This baseline analysis can help reduce demand by enabling scarce program funds to be focused on areas of highest need and greatest impact.

The complementary use of smart meter data analysis with social research provided new insights into the greatest opportunities for demand reduction and led to a more robust program design in Gunbalanya. The draft action plan was aimed at behaviour change and sought to trial and evaluate community engagement tools and appliance retrofits. These engagement tools were developed as a response to bulk meter data analysis, which showed 1000L per person per day.

The results of the baseline analysis offered a clear identification of the problem and the program was altered to be more robust and cost-effective. The mixed-method baseline suggested a concerted effort to address leaks throughout the system. Addressing maintenance and intermittent leaks became the primary goal of the program, shifting from an initial emphasis on household consumption. Modified program components that responded to the baseline analysis included the rollout of stainless steel taps, social marketing that centered on reporting leaks, and a community commitment to report all leaks (instead of water use targets).

This mixed-method baseline approach is transferable to all community types and means that demand management funds can be targeted, cost-effective and successful. This case study presents a framework for designing effective demand management programs using the insights afforded by smart meters and social research.

Employing a mixed-method baseline analysis, with both smart meter data analysis and social research, to inform program design prior to program implementation, provides greater potential for water savings by responding to and targeting the community-specific context. Engaging in a mixed-method

baseline analysis will identify the water use type and user group that requires the most attention, resulting in greater demand reduction and a greater return on investment than a generic program.

Future articles on this case study will demonstrate how smart meters can also provide an ongoing method of monitoring water usage changes and an active means of conducting ongoing demand management by advising customers, as well as supporting program evaluation.

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