Determining a Validated Water Balance in an Unmeasured System and Understanding Unmeasured Residential Customer Consumption.

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Abstract

An accurate water balance (water audit) is the foundation on which a water loss reduction strategy is founded. It is significantly more difficult to determine an accurate water balance if a large proportion of legitimate consumption is not metered. This paper describes the successful determination of average unmeasured residential consumption of 349 litres/capita/day using individual consumption monitors on a random sample of unmeasured residential customers in distribution systems operating with intermittent supplies. The paper details the meter technology selected for this work to ensure that it does not register volumes of air or suffer damage due to air passing through the meter.

In parallel with installation of the individual consumption monitors, a water efficiency survey was also undertaken on a random sample of unmeasured residential in order to investigate the scope for reducing residential customer consumption in the same systems. The paper details the telephone surveys and in-house audits used for the survey and the resulting customer water balance. The most surprising and useful outcome of this survey was the finding that an average of 44% of residential unmeasured consumption was due to storage tank overflows.

Keywords: consumption monitor; efficiency survey; water balance

Introduction

An accurate water balance (water audit) is the foundation on which a water loss reduction strategy is founded. Any errors in the determination of the volumes of real and apparent losses will introduce errors in the economic analysis of options and can ultimately lead to the selection of an inappropriate loss reduction strategy. For this reason, it is important that the accuracy of any water balance is validated before it is used as a building block for an economic analysis and the development of a loss reduction strategy.

There are many water utilities around the world which do not meter all of their customers, particularly their residential customers. Instead these customers are charged on some form of flat rate tariff, often linked to the rateable value of the property. It is clearly significantly more difficult to undertake an accurate water balance if a large proportion of legitimate consumption is not metered and many managers of such utilities use this as a reason why it is not possible to quantify the volume of real losses in their utility. However, while it is more difficult to determine an accurate water balance in such a utility, it is certainly not impossible.

This paper describes the two approaches to estimating unmeasured residential consumption, and the advantages and disadvantages of each method. It also describes the successful determination of average unmeasured residential consumption using individual consumption monitors on a random sample of unmeasured residential customers in distribution systems operating with intermittent supplies. The paper details the meter technology selected for this work to ensure that it does not register volumes of air or suffer damage due to air passing through the meter.

In parallel with installation of the individual consumption monitors, a water efficiency survey was also undertaken on a random sample of unmeasured residential in order to investigate the scope for reducing residential customer consumption in the same systems. The paper details the telephone surveys and in-house audits used for the survey and the resulting customer water balance. The most surprising and useful outcome of this survey was the finding that an average of 44% of residential unmeasured consumption was due to storage tank overflows.

Methods

Assessing Unmeasured Residential Consumption

A detailed, validated, water balance was recently undertaken in Trinidad and Tobago in order to obtain a reliable assessment of the volume of Non-Revenue Water (NRW) in the islands, as a component of the development of a Water Master Plan for the country. The greatest problem with undertaking this water balance was that only 1.5% residential customers are currently metered. The consumption data from these meters could not be used to estimate average unmeasured consumption because these customers were being charged on the metered tariff, influencing their demand. Furthermore, they were not installed on a random sample basis and most of these meters are not working correctly.

There has never been any reliable assessment made of unmeasured residential consumption volumes in Trinidad and Tobago, so the volume of this use was by far the greatest uncertainty in the water balance. In addition, only 17% of customers receive a 24/7 water supply. It was therefore necessary to develop a methodology to address these problems and develop a reliable assessment of this use component. Experience from the UK water industry was used to develop the methodology for this assessment.

The majority of residential customers in the UK are currently unmeasured, nevertheless the water industry regulators, particularly OFWAT, require the private water companies in England and Wales to submit reliable audited leakage figures. In order to satisfy this requirement, all these water companies have established statistically representative consumption monitors to determine the average level of unmeasured residential customer consumption and hence per capita consumption (PCC) within their area of supply.

Two alternative methodologies are used to obtain representative PCC values – individual household consumption monitors and small area consumption monitors. Best practice methods for both types of monitor were detailed in a 1999 UKWIR report. This report was reviewed by Tynemarch Engineering Ltd. in a 2007 report prepared for the Quinquepartite Group and the methodology was confirmed to still detail best practice.

The individual household consumption monitors consist of installing meters on a representative sample of unmeasured residential customer's services, but continuing to charge the customer on the unmeasured tariff. Small area consumption monitors are based on a small meter installed on a main feeding a small number of unmeasured residential customers. There are advantages and disadvantages to both approaches. The individual household monitors have the advantage that they are not affected by any leakage in the distribution system, however there is a concern that the presence of the meter may influence customer consumption behaviour. Conversely, the small area consumption monitors avoid this problem, but can be influenced by undetected leakage in the distribution system. Despite these concerns, the Tynemarch report confirmed that as long as the best practice methods were used, both methods gave reliable assessments of PCC.

It was not considered feasible to establish small area consumption monitors in Trinidad and Tobago due to the level of intermittent supplies in the system, the number of breaks caused by operation of the supply schedules and the difficulty of leak detection in intermittent supply areas, which would make it almost impossible to ensure that the distribution system within small area monitors in intermittent supply areas remained free of leaks.

Individual household consumption monitors were also considered problematic due to the problems of air being forced through meters in intermittent supply areas, which would result in false consumption volumes and meter damage with virtually all domestic water meters. However one meter, the Severn Trent SmartMeter, was identified that would not register volumes of air and would not be damaged by air passing through it. This meter uses a fluidic oscillator as the measuring element and has no moving parts. This meter was therefore selected as the ideal meter for obtaining accurate consumption data from intermittent supply areas and was actually used for every property in the consumption monitor for consistency.

These meters were installed on a completely randomly selected sample of unmeasured residential customers from across all of Trinidad and Tobago. The meters were installed, where possible, in a meterbox in the pavement, outside the customer's property boundary for ease of access. Small Hobo event driven data loggers were installed on a sample of the meters in order to investigate customer use patterns and the prevalence and volume of storage tank overflows.

Water Efficiency Surveys

In order to assess the scope for water efficiency savings within residential properties in Trinidad and Tobago, a water efficiency survey was undertaken. This survey was undertaken in two phases. The first phase was a telephone survey of 425 randomly selected unmeasured residential customers designed to establish basic information on the water using fittings and appliances within these properties, as well as to identify customers willing to allow internal water use surveys of their properties. It was expected that it would be possible to select 270 properties from the telephone surveys for internal water use surveys.

Validating System Input Volume

For Trinidad and Tobago, the level of confidence in the system input volume has the second greatest impact on the confidence in the resulting volume of real losses, after the level of confidence in the unmeasured residential consumption. In order to determine a validated water balance, it is normal to test the system input meters in order to identify any errors in the recorded volumes. However there are over 100 sources supplying the system in Trinidad and Tobago, making it impractical to test all of them. For this reason, the key system input meters, accounting for 75% of production were subject to field tests.

Three different methodologies are normally used to validate key system input meters. Where the network configuration makes it feasible to utilize an existing storage tank or service reservoir for the period of the test, a volumetric test offers the most accurate method of validating existing meter accuracy. If a volumetric test cannot be undertaken, the next most accurate method is to use an insertion electro-magnetic meter installed in series with the input meter at a tapping at least 30 diameters or more downstream of any fitting or valve that could prevent the development of a fully developed hydraulic profile at the tapping point. The least accurate validation method is to use a clamp-on ultrasonic meter in series with the system input meter, located at least 50 diameters or more downstream of any fitting or valve that could prevent the development of a fully developed hydraulic profile at the test point.

None of the pipework and tank configurations around the selected key input meters in Trinidad and Tobago allowed for a volumetric test to be undertaken, so an ABB Aquaprobe insertion meter was used in a suitable tapping point where possible.

Validated Water Balance

Following the validation work, a detailed water balance was determined, with 95% confidence limits using the PIFastCalcs module of the LEAKSSuite software.

Results and Discussion

Assessing Unmeasured Residential Consumption

The intention had been to meter 270 customers across the islands to provide an assessment of unmeasured residential consumption to a 95% confidence limit of +/- 6%, however it proved impossible to find many of the selected properties due to the quality of the customer name and address data held by WASA. As a result, it only proved possible to install 200 meters within the timescale of the project and meter readings were only obtained from 170 meters within the required timescale, providing an assessment to a 95% confidence limit of +/- 7.5%. The average consumption per connection recorded by the consumption monitors was 1.29 m^3 per connection per day, which equates to a PCC of 349 litres per capita per day (lpcd) at an average household occupancy rate of 3.67. This is the first time that a reliable assessment of PCC has been made in Trinidad and Tobago and the level of PCC determined is very high for a country like Trinidad and Tobago, where there is very limited outdoor irrigation use.

Due to the time limitations of this study, the data collected to form this assessment was based on data collected from October 2008 to January 2009. Ideally, a full year's worth of consumption data would be used to determine the PCC for the annual water balance. For this reason, the meters that have been installed will be left in operation and further data will be collected by the Water And Sewerage Authority (WASA) over the next year to allow the assessment to be updated once a full year's worth of data is available.

Water Efficiency Surveys

Due to a lower take-up rate than had been anticipated when the telephone survey was planned, only 188 random on-site household audits were completed to determine type, repair, and usage of water consuming fixtures and appliances. The results reported therefore have a 95% confidence limit of +/- 7.1%.

The water efficiency surveys were undertaken before the results were available from the PCC assessment. The water efficiency survey results are therefore expressed in terms of a PCC estimated from the surveys of 379 lpcd, which is higher 8.6% higher than the 349 lpcd determined from the consumption monitors.

Figure 1 summarizes the results of the on-site household audits. The key findings of potential water efficiency savings are detailed in the following section.

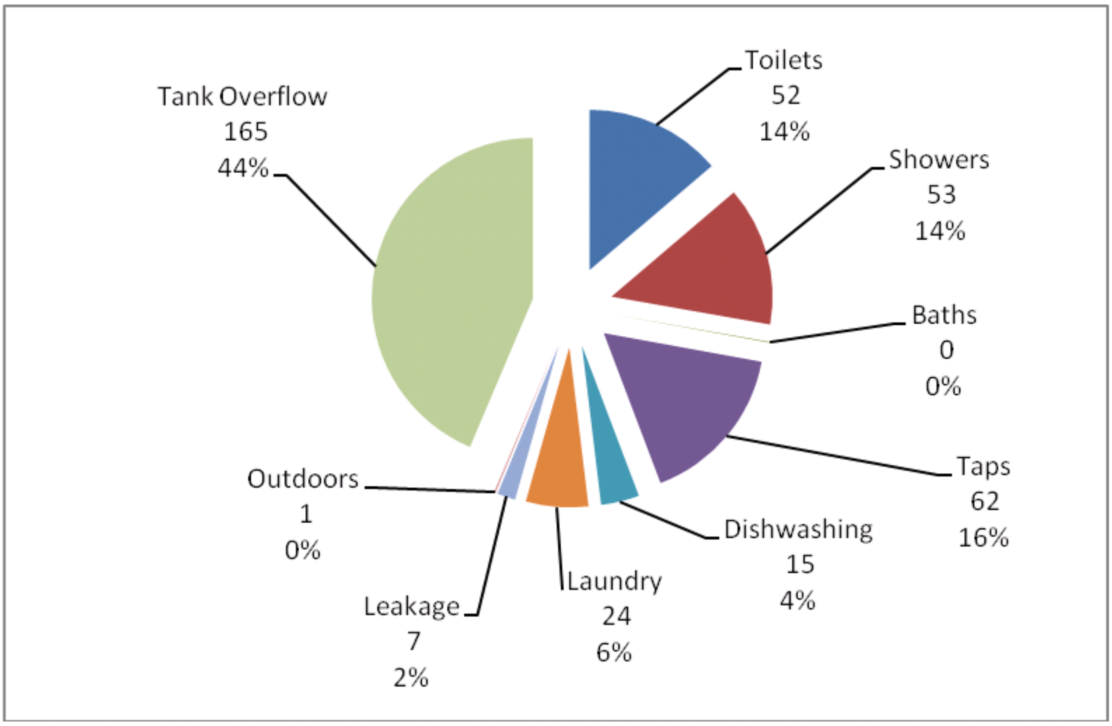

Figure 1 Weighted Average Residential Water Consumption (Lpcd)

Of the households audited, 83% had large storage tanks designed to provide storage to provide water when the mains are not pressurized. The survey found that 7% of these tanks were overflowing and 27% had the potential to overflow as they were not equipped with level controls. Although a small percentage was observed overflowing, the water wastage due to this condition is significant, accounting for 44% of the total unmeasured residential consumption. It is apparent that considerable water savings can be achieved through a proactive storage tank programme designed to reduce storage tank overflowing.

The high level of consumption from storage tank overflows also explains why the assessed PCC is so high. It also shows that resolving the problem of overflowing storage tanks, coupled with a real loss reduction programme, will make it possible to rapidly increase the areas of 24 hour supply in Trinidad and Tobago and improve the levels of service provided to customers.

During the household audits, it was determined that on average, toilets are flushing at 10.4 litres per flush. Toilet flushing accounts for 14% of the water use in the home. The amount of water used in flushing toilets can be reduced with the installation of ultra-low-flush toilets (ULF) that flush at 6 litres per flush.

There is an excellent opportunity to reduce water consumption associated with laundry. It was observed that 82% of the households had high water consuming top loading clothes washing machines. These machines consume 184 litres per cycle as compared to water efficient models that use only 56 litres per cycle. Six percent of the water consumed in the home is for laundry. This could be reduced by 60% with the installation of efficient front loading washing machines.

Validating System Input Volume

The field tests undertaken confirmed that the meters tested were accurate to within the accuracy of the test procedures. In addition, although the 95% confidence limits of the accuracy of the other meters not tested was lower (between +/-5% and +/-15%, depending on the particular source, because there are so many sources supplying the Trinidad and Tobago networks, the 95% confidence limit of the overall system input volume was within +/-2%.

Validated Water Balance

Table 1 summarizes the performance indicators determined for the validated water balance for Trinidad, based on the results of this study.

Table 1 Validated Performance Indicators for Trinidad Water Balance 2006/07

Performance Indicators	Best Estimate	95% Confidence Limit ±%	Lowest Estimate	Highest Estimate
NRW as % of System Input by Volume (Fi36)	36.2	9.7%	32.7	39.7
NRW % of System Input by Value (Fi37)	65.7	9.7%	59.4	72.1
Apparent Losses % of Water Supplied (Op25)	6.1	36.3%	3.9	8.3
Apparent Losses % of System Input Volume (Op26)	6.1	36.3%	3.9	8.3
Real Losses Litres/Service Connection/Day (Op27)	1524	12.4%	1334	1713
Real Losses Infrastructure Leakage Index ILI (Op29)	28.3	12.8%	24.7	31.9

It can be seen from this table that although over 97% of WASA's customers in Trinidad are unmetered, by using a consumption monitor it is possible to determine the real loss performance indicators with a reasonable level of confidence. The ILI for Trinidad is determined as 28.3 to a 95% confidence limit of +/- 12.8%. It is possible to determine an appropriate NRW reduction strategy with this level of confidence.

Conclusions

This paper has shown that it is possible to determine an accurate validated water balance in a largely unmeasured system by establishing a statistically representative consumption monitor to obtain a reliable assessment of unmeasured consumption.

The paper has also shown the benefit of undertaking a water efficiency survey as a part of an NRW assessment. The high level of consumption from storage tank overflows was an unexpected outcome of the water efficiency survey.

Resolving the problem of overflowing storage tanks, coupled with a real loss reduction programme will make it possible to rapidly increase the areas of 24 hour supply in Trinidad and Tobago and improve the levels of service provided to customers.

References

UKWIR Best Practice Report (1999), Best Practice for Unmeasured Per Capita Consumption Monitors

Tynemarch Engineering (2007), Leakage Methodology Review: Variation in Per Capita Consumption Estimates, Final Report for Quinquepartite Group