

APRIL 2022 - SCIENCE BRIEF

The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.



THE STATE OF DOMESTIC WATER METER MANAGEMENT

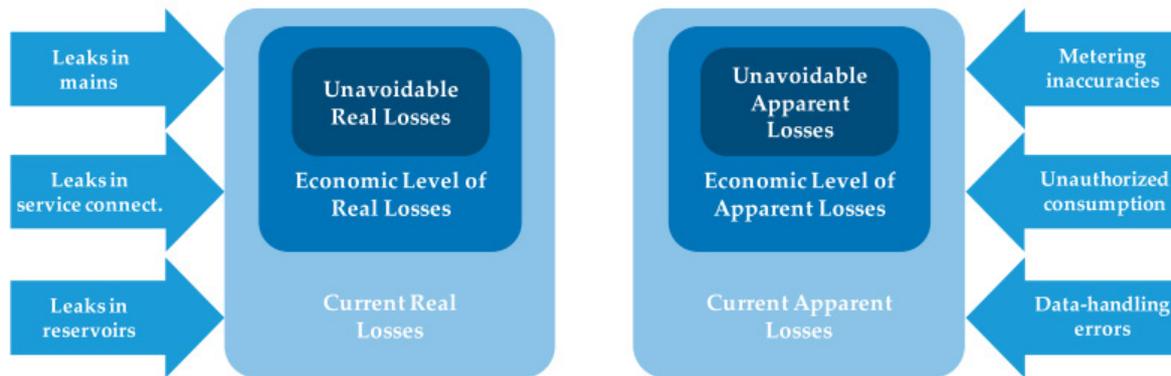
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High levels of non-revenue water (NRW) are a major challenge for municipalities and utilities worldwide, with estimates of NRW in South Africa having increased from 34.6% in 2013/14 to 41% in 2015/16 (Department of Water and Sanitation, 2017). Aligned to NRW is the aspect of good meter management as it impacts both the revenue collections as well providing a good record of water supplied and water utilised. A Water Research Commission (WRC)-funded study found that based on initial weighted accuracy of new meters assessed in South Africa, which is a first for South Africa and the African continent, the average accuracy of water meters in South Africa was determined to be 95.5% and is indicative of minimum apparent loss levels for a brand new meter. Current guidelines on possible apparent water losses need to be revised to reflect that a 4.5% initial apparent loss error is likely to be the best possible figure assuming an equal spread of the meters tested. This average error translates to a financial loss of R2.32 billion per annum lost from new meters in the municipal sector, assuming a retail water cost of R12/kl. Such losses will invariably be more for each year that meters remain in service and that alone should spur the sector to manage meters better.

High levels of Non-Revenue Water (NRW) are a major challenge for municipalities and utilities worldwide, with estimates of NRW in South Africa having increased from 34.6% in 2013/14 to 41% in 2015/16 (Department of Water and Sanitation, 2017). For a water scarce country, these levels of NRW are unsustainable, particularly against the background of projected increases in water demands. Moreover, this has implications for the financial viability of many municipalities and therefore, appropriately addressing

NRW challenges would be a key opportunity for many municipalities to unlock both resource and financial benefits (Green Cape, 2017).

Aligned to NRW, which is made up of several components as shown below, is the aspect of good meter management as it impacts both the revenue collections as well providing a good record of water supplied and water utilised. Any difference is indicative of water losses in the system.



Source: Arregui, Cobacho, et al. (2018)

To address the existing NRW challenges, it is imperative that the right interventions are identified, prioritised, and implemented. To support the identification of the right interventions, it is necessary to adequately understand the various components of NRW. One of the challenges associated with assessment of NRW is the reliability of the methods used for component analysis (Mutikanga, 2012). Apportioning water losses between physical (real) and commercial (apparent) losses is one contentious area. In South Africa, the conventional approach to accounting for Apparent Losses (AL), has not been from explicit quantification but rather through the reliance on rule of thumb estimations due to the lack of information and interrogation. Apparent losses comprise water that is not recorded correctly by a water meter but is likely consumed, including unauthorised consumption, as such a better measure is as a percentage of billed authorised consumption as opposed to a percentage of water losses. It can therefore be argued that without the explicit quantification of apparent losses, the interventions for managing NRW levels that are determined from the conventional approaches may not be adequately informed or optimum. Considering that apparent losses can reach up to 30% of total losses in terms of volume and 50% in terms of cost (Arregui et al., 2018), their estimation becomes paramount.

Assessment of apparent losses has mostly focused on metering which have been found to be the highest contributor to apparent losses (Rizzo & Cilia, 2005). This is because mechanical meters, which historically have been and remain the dominant meter type in use, experience reduced efficiency with age and usage due to wear and tear, incorrect installation, water quality, incorrect meter sizing, demand profile, among other factors (Ncube, 2019). A review of the practices and methods of apparent losses estimation and management shows that several AL estimation approaches have been developed and applied in many locations. However, the usefulness of the respective AL estimation approaches varies according to the extent to which assumptions underlying the methods lead to over-simplification. Cost is a key factor that heavily informs the choice of one approach over another. The reality is that the

methods that have the most utility for comprehensive water meter management come at a prohibitive cost for most municipalities in the country.

The Compulsory National Standards and Measures to Conserve Water (Regulation 509 of 2001) under the Water Services Act (Act 108 of 1997) prescribes the universal metering for all water connections. This sets the basic requirement for water metering for all municipalities. In addition, regulation requires the reporting of information and calculations relating to water losses which implies active management of the metering systems.

Water meters effect and measure custody transfer of water from the service provider to the consumer, and as such, the verification of their accuracy throughout their lifecycle is the subject of legal scrutiny. In South Africa, the Legal Metrology Act (Act 9 of 2014), which replaced the Trade Metrology Act, 1973 (Act 77 of 1973), and its regulations form the basis of such scrutiny. It requires that all measuring instruments be subject to initial verification and subsequent verification in accordance with the relevant legal metrology technical regulation. There are, however, very limited requirements for water meters in comparison to other measuring instruments in the regulations particularly on the on-going verification period. Referenced within the Legal Metrology Act is the South African National Standards (SANS) 1529 suite of standards which outline the performance characteristics, dimensions, type, approval requirements etc. for all metering devices used for trade purposes. It currently consists of four parts:

- **Part 1:** Metrological characteristics of mechanical water meters of nominal bore not exceeding 100 mm. Last revised in 2019
- **Part 3:** Physical dimensions. Last revised in 2006
- **Part 4:** Mechanical meters of nominal bore exceeding 100 mm but not exceeding 800 mm. Last revised in 2004
- **Part 9:** Requirements for electronic indicators used with mechanical water meters, electronic water meters and electronic prepayment water measuring systems. Last revised in 2019

Of relevance to meter management and apparent losses, the SANS 1529 standards require that:

- All water meters used for trade purposes must be type approved.
- The metrological class of a water meter describes the capacity of the meter to measure within prescribed tolerances of accuracy at prescribed flow rates which are expressed as ratios of the permanent flow rate as given in Table 1, with the overload flow rate being equal to 2 times the permanent flow rates.
- Only meters with metrological classes B, C and D may be used for trade purposes.
- Meter verification can only be carried out in accredited

institutions by the accrediting authority (i.e., SANAS) and shall be carried out in terms of SANS 1529-1: Annex B.

- The Permissible Tolerance on indication, which is the difference between the indicated volume and actual volume, shall not exceed the values given in Table 2.
- All water meters must be the subject of on-going verification and the users of water meters for trade purposes are responsible for ensuring that the water meters under their control are subject to that on-going verification.
- If any water meter becomes defective or its accuracy is not within the specified tolerances, it shall immediately be withdrawn from service by its owner or user.

Table 1: Metrological Class of Meters (SANS 1529)

Class of Meter	For q_p not exceeding 10 m ³ /hr		For q_p exceeding 10 m ³ /hr	
	Minimum flow rate, q_{min}	Transitional flow rate, q_t	Minimum flow rate, q_{min}	Transitional flow rate, q_t
A	0.04 q_p	0.10 q_p	0.08 q_p	0.08 q_p
B	0.02 q_p	0.08 q_p	0.03 q_p	0.03 q_p
C	0.01 q_p	0.015 q_p	0.006 q_p	0.006 q_p
D	0.0075 q_p	0.0115 q_p	-	-

Table 2: Permissible Tolerance on Indication (SANS 1529)

Meter Status	Flow Rates	
	Less than q_t	More than q_t
New & Refurbished meters	5%	2%
Meters in use	8%	3.5%

Despite the requirement that all meters shall be the subject of on-going verification and that once defective, meters must be removed from service, there is currently no guidance on how such on-going verification to identify defective meters should be done locally. This is one area that South African standards and regulations fall short. For contrast, one can consider the Australian Standard AS 3565, for example, which includes Part 4 (2007) that focuses on in-service compliance testing. This is further supported by a voluntary Water Services Association of Australia WSA 11 Code of Practice dealing with the Compliance Testing of In-Service Water Meters. The American Water Works Association (AWWA) also provides Manual M6 on Water Meters - Selection, Installation, Testing, and Maintenance which provides guidance of the testing of in-service meters, among other issues. Despite the lack of standards locally, there is some work that could be formalised and/or codified to manage meters better. Johannesburg Water (2016) is a metering specification and guideline manual that articulates how they intend to proactively handle meter management, including the testing of water meters. Ncube (2019, chap. 7) also offers a guideline on how water meters may be best handled for the enhanced management of apparent water losses. Both documents are therefore instructive on how municipalities and utilities can also better handle integrated meter management

Practically, the requirement that municipalities check the compliance of their meter fleet and take corrective action is imbedded in the existing regulations. However, there is very limited insistence or enforcement that this is done, despite the high levels of NRW in many areas. Distilling such requirements into easy-to-follow steps and guidelines will therefore be useful for the sector.

Although SANS 1529: 1 2019 has been updated in 2019, it remains relatively outdated to metering standards internationally. It still is closely aligned to the ISO 4064:2005 version whose most current version is 2014. Fortunately, some meter manufacturers, particularly international ones, already comply with newer regulations such as the EN 14154 and ISO 4064 standards. Both these standards are very similar to the International Organization of Legal Metrology (IOML) model standard in the form of recommendation R49.

Many South African municipalities do in fact carry out a variety of metering related activities without the express objective of quantifying and/or managing apparent water losses (Ncube & Taigbenu, 2018). These activities include the routine testing of water meters in response to consumer queries and complaints. Although the tests might not be significant individually, they become meaningful in combination with other tests, including those from similar municipalities. Ncube & Taigbenu

(2015) and Ncube (2019) have shown that these random tests, when collated and analysed, offer valuable insight into the degradation of metering error and other meter management criteria. The determination of statistically significant results per meter model, which would otherwise be either difficult or expensive for a single utility or municipality, becomes within reach.

It is against this background that the WRC-supported a study to collate existing water meter performance data from accredited laboratories, together with the generation of new meter testing data for the municipal water sector in the country. Through the creation of a freely accessible electronic database, the findings from the assessment of apparent water losses in South Africa will help facilitate the improved management of apparent water losses.

This provides a better basis of determining the useful life of water meters and how they can be better managed to improve the management of apparent water losses. While a metering framework exists in South Africa, its main limitations are that it is outdated, has limited requirements for water meters when compared to other measuring instruments and offers no guidance on the testing and management of in-service water meters. This therefore hampers best practice in water meter management and the management of apparent water losses in general as standards define what is possible and permissible. On the other hand, the paucity of work on apparent losses also perpetuates the stagnation in standards development. Quantifying and understanding locale specific reference values of apparent losses could potentially provide an impetus in the adoption of metering standard that minimises apparent water losses.

Outputs from Stakeholder Engagement Sessions indicated the following:

- Inadequate regulations/standards/guidelines for in-service water meter testing.
- Meter testing is largely reactive at the behest of the customer and is inadequate.
- Pervasive use of spreadsheets for meter testing data with limited analysis of the records.
- Meter testing according to SANS 1529 does not reflect field conditions.
- Meter replacement periods are largely based on Rule-of-thumb estimates with no scientific basis.
- Inadequate funding allocations cited for limited meter replacements programmes, where such programmes exist.
- Availability of illicit metering products on the market.
- Ownership, custodian, and control of the database product was a concern and how users will be registered and use the database for only non-commercial and authorized uses.
- Structural sector issues such as the voluntary SABS Mark which manufacturers can opt out for thereby exempting them from quality control requirements of the mark.

A key aspect of the study was the collation and analysis of historical meter testing data from participating municipalities. While over 5,613 records were obtained from five municipalities, only 4,385 records from three municipalities could be used for analysis. Only one municipality has an accredited laboratory with the rest of the municipalities using one meter manufacturer's laboratories. The bulk of meter manufacturers also tend to only test their meters which limits meter testing options.

The age of the meters tested could only be determined for 2,344 meters using the serial number logic as the age information is not included in the test results. The bulk of the meters had been in use for less than five years. On the other hand, the meter reading, which is available for all meters showed that a large proportion of the meters had registered well over 10,000m³. To put this in perspective, using an average domestic monthly consumption of 30m³/month, such a typical consumer meter will take over 27 years to reach that volume, which is excessive.

The probability of failure analysis showed degradation rate of 0.01% - 0.02% per 1,000m³ of volume registered with starting probability of failure for most meters being around 25% and up to 50% for one meter model. The degradation rate with age had much higher rates at 1%, 3%, and 6% per year for some models with starting probability of failure of 25%, 9.5% and 4% respectively. The high starting probability of failure was validated through the testing of new meters.

To determine the weighted accuracy of the meters that were historically tested, the consumption profile of Johannesburg was used together with the test results of each meter. The implicit assumption being that the consumption profile of Johannesburg is similar to that of other cities and towns. There was no meaningful relationship of the weighted meter error with registered volume for all the meters in the dataset. However, one meter model showed a strong relationship between weighted error and meter age where the error increased annually by 1.2% with a starting error of 8.7%. The high starting error was also validated through the testing of the new meters.

Despite the weakness of using data that could be of meters that were at the end of their useful life due to reactive meter testing, there are some clear informative trends that the sector can use to manage meters better. Better data collection and standardisation of the testing and test reports, together with more proactive testing would make such analysis even more useful. To counteract some of the challenges currently being experienced in the sector, a meter management database called the Meter Performance Monitor was developed as part of the research. The Monitor can handle activities ranging from capturing meter accreditation data, individual test reports, importing historical testing data, analysis and reporting all within a centralised platform that can consolidate data from different municipalities, flow laboratories and the NRCS.

The common meters that were being used and tested by the participating municipalities were reviewed to determine with the predominant meter models. Seven meter models were identified, and these were purchased from the sales department of a manufacturer, or authorised sale representatives, as would be purchased by any customer. The purpose of the purchases was not disclosed to ensure that meters that would have been purchased by any member of the public were also offered to the project.

As a first step, it was important to determine the optimal number of test points for South Africa using two main local studies that had evaluated meter accuracy by testing at ten flowrates. In either case, using the raw data of each of the study, the weighted accuracy was recalculated for each of the test records by varying the number of test flowrates (3 – 10 flowrates) used to estimate the weighted error. The weighted meter accuracy increased with increasing number of flowrates, or conversely the error decreased with the increasing number of test flowrates. The best estimate of the meter accuracy was achieved at 10 flowrates, with 4.74% difference in weighted accuracy when calculated using three common flowrates (q_{min} , q_t , and q_p). The inadequacy of the common use of three test flowrates for the estimation of meter error and the weighted meter accuracy is clearly demonstrated in this case. Through various trials, the optimal number of test points was found to be seven test flowrates of 7, 15, 30, 60, 120, 1,500 and 3,000ℓ/h which only underestimated the weighted accuracy by 0.05%.

Using the adopted test flowrates, the project evaluated 101 new water meters of seven different models that are common in South Africa to determine their initial weighted accuracy and applicability for local conditions. Only about 40% of the meters tested were fully compliant with the SANS 1529 when evaluating their accuracy over the entire meter error envelope. This suggests that the values obtained from the probability of failure analysis are indeed plausible and therefore validated. While the meters would pass if only evaluated at the common three test points, this failure rate indicates that manufacturers may tend to calibrate the meters to pass at only those points but neglect the rest of the operational points. It was also shown that neither the meter class nor its technology are necessarily good predictors of the ability of a meter to pass or to have superior accuracy. Therefore, it is important to collect and collate meter performance data regularly to be able to evaluate and uncover such anomalies and be better informed in making meter management decisions.

The study found that based on initial weighted accuracy of new meters assessed in South Africa, which is a first for South Africa and the African continent, the average accuracy of water meters in South Africa was determined to be 95.5% and is indicative of minimum apparent loss levels for a brand new meter. Current guidelines on possible apparent water losses need to be revised to reflect

that a 4.5% initial apparent loss error is likely to be the best possible figure assuming an equal spread of the meters tested. This average error translates to a financial loss of R2.32 billion per annum lost from new meters in the municipal sector, assuming a retail water cost of R12/kl. Such losses will invariably be more for each year that meters remain in service and that alone should spur the sector to manage meters better.

A further demonstration of the implication of the results has also been done and it indicates that based on the starting error of the common meters, and an average degradation rate of 0.7% per year, the average meter replacement period of local meters should be 10 – 11 years for a typical consumer who uses 360kl per year. The financial losses, on average, for 10 year old meters are expected to be in the region of R5.92 billion per annum.

Key recommendations emanating from the study are (i) the establishing of Norms and Standards for water metering; (ii) updating the Legal Metrology Regulations aspects relating to Water Meters, ideally by incorporating them with (i); (iii) updating the SANS 1529 suite of standards; (iv) establishing mandatory meter and consumer audits that will inform meter management annually.

References

- Arregui, F., Cobacho, R., Soriano, J., & Jimenez-Redal, R. (2018). Calculation Proposal for the Economic Level of Apparent Losses (ELAL) in a Water Supply System. *Water*, 10(12), 1809. <https://doi.org/10.3390/w10121809>
- Department of Water and Sanitation. (2017). *Benchmark of Water Losses, Water Use Efficiency and Non Revenue Water in South African Municipalities (2004/05 - 2015/16)*.
- Green Cape. (2017). *Water – 2017 Market Intelligence Report –*.
- Johannesburg Water. (2016). *Water Metering Guidelines and Specifications* (Issue June).
- Mutikanga, H. (2012). *Water Loss Management: Tools and Methods for Developing Countries*. CRC Press/Balkema.
- Ncube, M. (2019). *Decision Enhancement for the Management of Apparent Water Losses* [University of the Witwatersrand, Johannesburg]. <https://hdl.handle.net/10539/28791>
- Ncube, M., & Taigbenu, A. (2015). Meter Accuracy Degradation and Failure Probability based on Meter Tests and Meter Change Data. *Proceedings of the 4th YWP-ZA Biennial Conference and 1st African YWP Conference*.
- Ncube, M., & Taigbenu, A. E. (2018). Decision Enhancement for the Management of Apparent Losses. *Proceeding of the Biennial WISA 2018 Conference*.
- Rizzo, A., & Cilia, J. (2005). Quantifying meter under-registration caused by the ball valves of roof tanks (for indirect plumbing systems). *Proceedings of the Leakage 2005 Conference, ...*, 1–12.