Ministry of Water & Sanitation

WASREB
Water Services Regulatory Board

Non-Revenue Water Audit of WSPs

Final Report

Findings and Recommendations

August 2018

Financed by: UKaid from the British people

Developed by: ATKINS

Supported by: KENYA MARKETS TRUST Better Markets, Better Lives; SNV

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Foreword

The Non-Revenue Water (Audit) Report of Water Service Providers is a reflection on the NRW situation in the country. The audit, undertaken in nine (9) WSPs, with the support of the Netherlands Development Organization (the "SNV") and Kenya Market Trusts, shows the huge gap that exists between targets set by Wasreb and the reality on the ground.

Findings show that NRW levels among the WSPs studied range from 31% for Malindi to 85% for Nakuru Rural. This paints a grim picture for the sector. According to Wasreb benchmarks, a NRW level of under 20% is regarded as 'good'; 20-25% is regarded as 'acceptable'; while over 25% is 'not acceptable'. This means that none of the nine WSPs studies is anywhere near the acceptable NRW levels.

Reducing NRW is therefore a high priority for the water sector in Kenya. The goal of the National Water Services Strategy is to reduce NRW to under 30%, while the Vision 2030 goal is to reduce this to under 25%. The sector benchmark for NRW is 20%.

Wasreb appreciates the support of development partners and other stakeholders for their commitment in efforts towards curbing NRW in the country.

Eng. Robert Gakubia
Chief Executive Officer

The goal of the National Water Services Strategy is to reduce NRW to under 30%, while the Vision 2030 goal is to reduce this to under 25%. The sector benchmark for NRW is 20%.

Executive Summary

This Final report describes the Non-Revenue Water (NRW) audit undertaken of nine Water Services Providers (WSPs). It is based on consultations with the WSPs, and field tests undertaken between August and December 2017. More detail for each WSP is provided in the nine Findings Reports.

An assessment of the average NRW within each of the nine WSPs for 2017 was conducted, and figures range from 31% (Malindi) to 85% (Nakuru Rural), which are within -2.5% and 21.7% of the figures reported to WASREB for the Impact 2017 report. Of the nine WSPs, the consultant had high confidence (NRW within +/- 2.5%) in two WSPs, medium confidence in a further two (+/- 10%), and low confidence in five (-10 to +25%).

Eight categories of best practice have been identified, along with five key challenges for effective NRW management, as follows:

Best Practices

- Effective meter reading;
- Effective customer metering;
- Pressure management;
- Effective NRW reporting;
- Adoption of GIS;
- Establishment of DMAs;
- Proactive and effective illegal connection team; and
- Effective customer engagement.

Key Challenges

- System Input metering unreliable;
- Not all customers metered;
- Customer meters stalled/ inaccurate;
- Very poor infrastructure; and
- Intermittent Supply.

To address these challenges a five-stage approach has been proposed and that recognises that each WSP is at a different level of maturity at present. The five stages comprise:-

- **Stage 1** ("No Regrets" actions, representing activities which can be implemented now before better data are available to inform decisions)
- **Stage 2** (Improve data and confirm plan)
- **Stage 3** ("Quick Wins")
- **Stage 4** (Create sustainable NRW infrastructure)
- **Stage 5** (Sustain NRW reductions)

For each WSP, it was highlighted the current position against these stages, along with the immediate tasks required to progress to the next stage. These describe what needs to be implemented, and with particular focus on the tasks where external support (for example from SNV) would be beneficial.

The proposed four areas where NRW management can be improved at a national level are:

1. Technical Assistance;
2. Regulation;
3. The organisation of WSPs; and
4. Stakeholder engagement.

These can be used as the basis to plan how to realise the five-stage approach.

Standards for NRW management in Kenya were reviewed and concluded that they are generally a good guide for NRW reduction in Kenya, with four key areas where the Standards could be enhanced (the quality of repairs, limitations of cost benefit analysis, customer engagement, and the need to adapt the approach to the current level of maturity).

01 Introduction

Reducing Non-Revenue Water (NRW) is a high priority for the water sector in Kenya, the National Water Services Strategy goal is to reduce NRW to under 30%, and the Vision 2030 goal is to reduce this to under 25%. WASREB define a level of NRW of under 20% as 'good', 20-25% as 'acceptable', and over 25% as 'not acceptable'.

The Netherlands Development Organization (SNV) in partnership with Kenya Markets Trust (KMT), is implementing the Climate Resilient Water Services (CREWS) programme as part of its water sector strategy to realize transformational change in the sector. One of the CREWS objectives is to contribute to the reduction of NRW in the water sector from 44% to 38% over the next three years. Aware of the current trend (i.e. 1% annual reduction), SNV aims to accelerate this rate by an additional 1% reduction over the next three years. To achieve this, one of the focus intervention areas will be to provide support to urban Water Services Providers (WSPs) in NRW management, using innovative methods. This NRW Audit has been conducted with financial support from UKAID.

Nine urban WSPs have been selected to develop NRW strategies in line with the Water Services Regulatory Board (WASREB) NRW handbook and manual, identify District Metering Areas (DMAs) and implement NRW strategies through conventional approaches and performance based contracting. The support to develop the NRW strategies will be informed by findings of a comprehensive NRW study/audit.

Creating DMAs is key to managing NRW; a DMA comprises a discrete area within the distribution network (typically serving 500 to 1500 connections), with meters on all inflows (ideally the area will be single-feed). DMAs allow a water balance to be derived at a lower level so that the levels of physical and commercial losses can be assessed and targeted effectively. DMAs should be continuously monitored (the inflow should be reviewed daily), so that increases in leakage which can be detected when the minimum nightflow increases, can be identified quickly. The water utility can then deploy leakage detection and repair gangs to find and repair leaks and restore leakage levels to a low base level.

1.1. Overview of objectives

The objective of this assignment was to conduct a comprehensive NRW audit (including components & causes) for the 9 urban WSPs, with the intention to inform their management on the need for development of SMART and NRW response strategies in line with the WASREB NRW management standards.

1.2. Summary of work undertaken

The methodology was to undertake a literature review for each and then to:

- Request and obtain data related to NRW to enable a maturity assessment against the NRW management guidelines to be undertaken;
- Hold an initial meeting with the WSP;
- Carry out a field test;
- Analyse and clarify data received from the WSP; and,
- Complete a maturity assessment against the NRW management guidelines for each WSP;

- Prepare a Water Balance for each WSP;
- Prepare a findings report for each WSP;
- Collate the overall findings in a Summary report (this document).

A number of constraints were faced when undertaking the project, in particular the quality and availability of data. The scope of this project was an audit rather than data improvement, but experience was drawn across all the nine WSPs, and also from experience elsewhere to supplement the data shortfalls.

For example, an ideal pilot area would comprise of a discrete established DMA, with continuous supply, a working meter, plotted on GIS (customer meters), and representative of the WSP as a whole. None of the pilot areas met all of these criteria. To make the pilot areas most useful, priority was given to areas which were discrete and subject to generally continuous supply. Having selected pilot areas on this basis, it was still found that a number did not have a continuous supply during measurement, and this limited the leakage analysis that could be undertaken.

To verify System Input (SI) meters, ideally a reference meter would be installed adjacent to an existing working SI meter, to validate the accuracy of the WSP meter. In a number of cases there was no System Input meter on the outlets from treatment works, or meters were not functioning. Furthermore, it is worth noting that the accuracy of ultrasonic clamp-on meters (which were used to verify the WSP meters) were constrained by site conditions. The presence of air can affect the accuracy of Ultrasonic Flow Meter (UFM) readings, and the meter needs to be installed on a straight length of pipe, (which was generally accomplished).

It was found that the quality of data from WSPs was variable, in different formats, and could be difficult to obtain. The uncertainty in the data in which the Water Balance has been derived, was taken account of, based on the following principles (where 1 is the highest quality data and 5 the lowest):-

1. Independently measured data (eg. System Input meter verification by UFM);
2. Data from WSP, reviewed and checked against other sources or independent report (eg. monthly water balance and checked against System Input test);
3. Data from WSP, reviewed but no other source available for checking;
4. WSP verbal/written report; and
5. Judgement based on observation and experience elsewhere.

During the assessment, the level of confidence in the NRW figure derived varied as follows:-

- High confidence – key data quality 1 or 2;
- Medium confidence – key data quality 3 or 4;
- Low confidence – key data quality 5.

In carrying out the audit, the three key sources used to assess and compare performance were as follows:-

- The Standards for Non-Revenue Water Management in Kenya published by the Ministry of Environment, Water and Natural Resources in 2014;
- The International Water Association (IWA) practices and procedures;
- International experience of managing water losses.

02

Findings Report

2.1. Overview of findings

A Water Balance for each WSP was derived and a summary is given in Table 2-1 below. The confidence in NRW has been assessed in accordance with the guidelines given in Section 1.2. The maturity of each WSP in terms of managing NRW was assessed against WASREB's NRW guidelines, and the findings for all WSPs are shown in Table 2-2. The guidelines for the maturity assessment are given in Table 2-3 .

The findings are expanded in the sections that follow where best practice, challenges and recommendations are described.

Table 2-1: Water Balances in each WSP

WSP	Impact Report		Our Assessment				
	2015-2016 NRW (%)	2016-2017 NRW (%)	NRW (%)	Commercial Loss (%)	Physical Loss (%)	Annual value (Ksh m) of NRW at average tariff (Ksh 83/m^3)	Confidence in reported NRW
Eldoret	49.9%	43.1%	40.5%	3.1%	37.3%	481.2	Moderate
Thika	32.0%	31.3%	33.8%	6.6%	27.3%	315.0	Low
Kakamega	49.0%	43.1%	54.6%	18.6%	35.9%	256.3	Low
Malindi	33.6%	30.7%	31.7%	4.9%	26.9%	140.8	High
Murang'a South	63.6%	60.0%	76.9%	10.5%	66.4%	277.4	Low
Embu	46.4%	42.6%	40.9%	22.7%	18.2%	250.5	High
Nakuru Rural	63.4%	63.3%	65.1%	15.1%	50.0%	453.5	Low
Nanyuki	34.6%	38.4%	40.8%	1.8%	38.9%	127.1	Moderate
Isiolo	33.6%	39.2%	43.4%	0.3%	43.1%	46.8	Low

Notes

1. Confidence in reported NRW corresponds to the following likely levels of uncertainty in NRW:-
   a. High +/- 2.5%
   b. Moderate +/- 10%
   c. Low-10%, +25%
2. The total annual value of NRW in the nine WSPs at the average tariff (Kshs 83/m3) is Kshs 2,349 million.

Table 2-2: Maturity assessment summary

Ref	Description	Thika	Muranga S.	Malindi	Nanyuki	Nakuru R.	Eldoret	Kakamega	Embu	Isiolo
1	**Water Balance, Flow and Pressure Monitoring, Mapping**									
1.1	Water Balance	D	D	C	C	D	C	E	C	D
1.2	System Input Metering	E	E	B	C	E	C	E	A	D
1.3	Pressure Monitoring	E	E	E	E	D	D	E	C	E
1.4	Maps/GIS	C	D	D	B	D	D	C	C	D
2	**Leak Repair Records**									
2.1	Leak Repair Records	C	C	C	C	D	E	D	C	C
3	**Performance Indicators**									
3.1	Performance Indicators	B	C	D	B	B	C	D	D	D
4	**Active leakage control**									
4.1	Active leakage control	D	C	C	B	D	C	E	C	D
4.2	District Meter Areas (DMAs)	D	E	D	B	C	E	D	C	D
4.3	Leak Repair- Distribution Pipes	C	E	C	C	C	D	E	C	E
4.4	Leak Repair- House Connections	C	E	C	C	C	D	E	C	E
5	**Customer Metering**									
5.1	Customer Metering	A	B	A	A	E	B	B	A	A
5.2	Customer Meter Replacement and Age	E	D	D	C	E	B	C	E	A
5.3	Customer Meter Class	C	C	C	D	C	C	C	C	B
5.4	Customer Database	C	C	B	B	C	B	B	C	C
5.5	Customer Meter Reading	C	C	A	B	B	B	A	B	C
5.6	Illegal Connections	C	C	C	A	C	B	C	D	A
6	**Other Interventions**									
6.1	Capacity building on NRW	D	C	C	C	C	B	C	B	C
6.2	Stakeholders awareness on NRW	D	C	C	B	B	A	B	D	B

LEGEND

A	Best Practice	B	Good	C	Average/satisfactory	D	Poor	E	Non Existent

Table 2-3: Maturity assessment guidelines

Ref	Description	Definition of standard under each grade				
		E Non-existent	D Low compliance	C Satisfactory	B Good	A Best practice
1	**Water Balance, Flow and Pressure Monitoring, Mapping**					
1.1	Water Balance	No Water Balance prepared	Annual Water Balance 1 year, or with high uncertainty	Annual Water Balance (>2 years), physical/ commercial losses split.	Annual Water Balance input metering 2	Annual Water Balance input metering 1
1.2	System Input Metering	No production meters	30-80% of flow measured by working meters	>80% of flow measured by working meters (not calibrated)	>80% of flow measured by working meters, 50% calibrated in last 5 years and within 5%	All flow measured by meters calibrated in last 5 years and within 5%
1.3	Pressure Monitoring	No pressures measured	Pressure in major zones measured once in the last five years	Key pressures logged, pressure survey in last two years	Pressures at the main inflow points logged	Continuous monitoring of pressures across the system
1.4	Maps/GIS	No records	> 70% of the network covered by paper records	Whole network covered by paper records or GIS which are kept up to date	>80% of network on GIS, but not completely verified	Whole network on GIS, verified on site and with procedure to update
2	**Leak Repair Records**					
2.1	Leak Repair Records	No central records	Records for < 2 years, data uncertain data.	Repair records >= 2 yrs. Maybe unable to track repair times or reported/ detected split.	Record of repairs with reported and detected separate, repair times tracked.	Central record on GIS, reported/ detected separated, repair times tracked
3	**Performance Indicators**					
3.1	Performance Indicators	No KPIs	Some targets but not recorded.	Annual record of performance against KPIs.	KPIs measured quarterly, some targets, but limited review.	Annual KPIs set, measured monthly, reviewed annually
4	**Active leakage control**					
4.1	Active leakage control	None	Adhoc (visual) patrols according to need.	Regular patrols (visual) to identify leaks, average repair times < 5 days	Regular patrols, daily/weekly monitoring of 25-70% of network.	Daily leakage monitoring (>70 % network), leak surveys, av. repair times < 3d

Ref	Description	Definition of standard under each grade				
		E Non-existent	D Low compliance	C Satisfactory	B Good	A Best practice
4.2	District Meter Areas (DMAs)	None	>50% of production measured and analysed monthly	>70% of production measure, analysed weekly, 1 or more pilot	>65% of network covered by continuously monitored DMA, weekly review of nightlines	>80% of network covered by continuously monitored DMA, daily review of nightlines
4.3	Leak Repair - Distribution Pipes (Repair Time)	Not recorded	Average < 1 week	Target of 1 day, 50% meet target, av. < 5 days	Target of 6 hours,750% meet target, av. < 3 days	Target of 6 hours, 90% meet target, av. < 2 days
4.4	Leak Repair - House Connections (repair time)	Not recorded	Average < 1 week	Target of 1 day, 50% meet target, av. < 5 days	Target of 6 hours,750% meet target, av. < 3 days	Target of 6 hours, 90% meet target, av. < 2 days
5	**Customer Metering**					
5.1	Customer Metering	Not known or coverage < 50%	Coverage 50-80%	80% coverage	90% coverage	100% coverage
5.2	Customer Meter Replacement and Age	Age not known	50% of meters < 8 yrs. old. Age of others unknown	60% of meters < 8 yrs. old. Age of others unknown	80 % of meters < 8 years old, some tests on meter test bench	All meters < 8 years old, regular tests on test bench
5.3	Customer Meter Class	Not known	> 30% Class B	80% Class C or D	70% class D, others class C	All Class D
5.4	Customer Database	No database	Paper record of customers	Simple central database	Central database that can be linked to system or zone.	Computerised database linked to GIS
5.5	Customer Meter Reading	Meters read on ad-hoc basis	Monthly reading but records held by individual readers, limited checking	Monthly, meter readers rotated, robust system to check readings	As C but photo verification partially rolled out.	Monthly, photo taken to verify meter reading
5.6	Illegal Connections, meter tampering, bypasses	No surveys	Meter readers check en route, limited disconnections	Meter readers check en route, then illegal connections disconnected	Surveys in response to anomalies, meter readers check en route, disconnections	Regular surveys by dedicated team, investigate anomalies, disconnect illegal connections

Ref	Description	Definition of standard under each grade				
		E Non-existent	D Low compliance	C Satisfactory	B Good	A Best practice
6	**Other Interventions**					
6.1	Capacity building on NRW Management	No training provided.	Some training in last 5 years.	Half the NRW team have received training in last 2 years.	Training plan, annual record of training.	Training plan, annual record of training and skills assessment.
6.2	Stakeholders awareness on NRW Management	No water efficiency campaigns.	Ad-hoc campaign undertaken > 3 years ago.	Bills raise awareness of water efficiency.	One campaign in the last two years.	Regular water efficiency campaigns (media, web-site).

2.2. Best Practices

Eight best practice categories were identified as shown in Table 2-5 . Best practice in the Kenyan context under each category is described.

Effective Meter Reading

Meters are read manually and the readings are then entered into a smartphone on site and uploaded automatically into a billing database. The database then runs checks to identify anomalies that would suggest an erroneous reading. The smartphone may be used to photograph (though not always used) the meter when it is read, which enables anomalies to be resolved without a further site visit, but also provides a means to check (via the time stamp and location) that the meter has been actually read. This system provides an effective means of monitoring both consumption and meter readers performance.

Even if the system is working well, it was still recommend that meter readers are rotated.

Effective Customer Metering

Mechanical customer meters tend to deteriorate with age and then under-register and stall, and they should be replaced at the latest when the cost of lost revenue exceeds the cost of replacement. In water scarce areas (which applies in Kenya), earlier replacement to incentivise water efficiency should be considered. In either case, it is likely that meters should be replaced after no more than eight or possibly up to twelve years. Class D meters are the most accurate, but as a minimum Class C meters should be used. To demonstrate the difference between the accuracy of meters in different classes, the accuracy of 15mm meters in Class B, C and D is shown in Table 2-4 below.

Table 2-4: Customer meter accuracy (for 15mm meter)

Accuracy	Minimum flow-rate (l/hour) at this accuracy for meters in Class:-		
	B	C	D
+/- 5%	30	15	11.25
+/- 2%	120	22.5	17.25

Best practice would involve regular random testing (on a test bench) of a statistical sample of customer meters, which is used to inform and support a replacement programme which ensures replacement of stalled or faulty meters within a month, and other meters when they reach the appropriate age. It was found that in most WSPs the accuracy of customer meters was poor and failure rate high; Isiolo was an exception in that 60% of meters were replaced in 2013.

Pressure Management

Pressure Management provides a cost-effective means of reducing physical losses, and to a lesser extent bursts and customer use/wastage. International best practice is to implement sophisticated pressure management (closed loop control or flow/time modulated control) where it can be used to deliver additional leakage savings and control flexibility. This approach may not be appropriate or beneficial in the local context, but the benefits of pressure management were demonstrated in Embu under the case study implemented as part of the Standards for NRW Management in Kenya project. Control by fixed outlet PRVs would deliver significant benefits in a number of WSPs.

Effective NRW Reporting

In order to drive NRW down to the low levels required by WASREB, WSPs need to report and monitor NRW and its components accurately. This then enables effort to be targeted to the most appropriate areas. At a high level, this means preparing a monthly water balance which indicates the main components of NRW (in particular the split between commercial and physical losses). It also entails reporting at a lower level (typically DMA level) to provide greater confidence in the top level assessment, and also enable effort to be targeted geographically. Finally, Key Performance Indicators (KPIs) with targets, provide a means to confirm each month that NRW is under control, and to identify if remedial action is required. KPIs would include:-

- NRW separated into physical and commercial losses;
- Bills based on estimated readings;
- Average age of customer meters, and number over, say 8 years old;
- Leaks detected and repaired and average repair times (split by mains and supply pipes);
- Reported leaks repaired and average repair times (split by mains and supply pipes); and
- DMA which are operational.

None of the WSPs audited demonstrated this level of reporting, but Thika did have some KPIs and monitored performance against them each month.

Adoption of GIS

Among many other benefits, a Geographical Information System is a powerful tool for managing NRW, its uses in this area include:-

- Assisting in DMA design;
- Identifying potential illegal connections;
- Leakage reporting; and
- Plotting failures and identifying hotspots to inform mains replacement programmes.

The use of GIS in Embu was demonstrated, where, it was possible to remotely identify potential unbilled users by overlaying customer meter data on base mapping. None of the WSPs audited are exploiting the full capabilities of GIS, but Nanyuki have a useful dataset on which to build.

Establishment of DMAs

Creating DMAs has been long established as a key tool to manage leakage; this remains the case in the project context despite the impact of more recent advances in Active Leakage Control technology.

Continuously monitored DMAs provide an effective means of controlling physical and commercial losses. Once correctly commissioned, they provide an effective means of identifying the split between commercial and physical losses (which are tackled differently). The real benefit of a DMA is realised when minimum night flows are monitored daily, so that significant increases in leakage can be identified and addressed within a day of breaking out.

It was found that whilst a number of WSPs had created DMAs, they were not being exploited to reduce leakage to a low level.

Proactive and effective illegal connection team

A prerequisite for managing illegal connections is "good housekeeping" with respect to meter reading, billing and regular rotation of meter readers. Putting these measures are in place (as described under Meter Reading and Customer Meters above), forms the foundation of an effective illegal use campaign. The key components to address illegal use are to:-

- Proactively investigate disconnected accounts that do not request reconnection (on the basis that they probably get water from somewhere);
- Regularly patrol the network with an independent team of dedicated staff who patrol areas that are not their home territory;
- Independently review major users (such as car washes), by reference to remote mapping or visual inspection;
- Review metering anomalies, so that meter tampering can be quickly identified;
- Reconcile DMA flows by comparing the monthly water balance with the leakage assessment; and
- Provide appropriate incentives to customers and staff to identify illegal connections.

To be effective, the investigations above need to be accompanied by a robust policy to disconnect customers that do not pay their bills, or take water illegally.

Effective customer engagement

Water is scarce in Kenya, and in many WSPs both the level of service to existing customers (in terms of continuity of supply) as well as service coverage are constrained by water resource capacity. High losses (both in terms of NRW and wastage by customers) make this situation worse, and also increase demand on the network which decreases pressure.

This can result in a downward spiral of increasing losses accompanied by deteriorating service levels. Engaging effectively with customers can help to reduce NRW and wastage, and we recommend that both should be addressed to together.

Effective stakeholder engagement means adopting a range of approaches so that many customers are reached. In all cases, the aim should be to present information in a relevant manner (not too technical), and to highlight benefits to customers, and cover aspects such as the need to pay for water, reporting illegal use and leakage, and water conservation.

Methods of engagement include barazas, local radio and newspapers, the WSP website and bills, and social media. Targeting large water users can be effective and we note that Eldoret are targeting healthcare institutions in such a manner.

Table 2-5: Best Practices

WSP	Examples of Best Practice							
	Smart Phone used for meter reading	Customer meters new and accurate	Pressure Management in place	Effective Leakage Reporting	GIS accurate and used to for analysing NRW data	DMA establihsed and ALC effective	Proactive and effective illegal connection team	Effective customer engagement
Eldoret	■						■	■
Thika				■			■	
Kakamega	■							■
Malindi	■							
Murang'a South							■	
Embu	■		■					
Nakuru Rural	■							
Nanyuki	■				■			
Isiolo		■					■	

LEGEND ■ Good example of best practice

2.3. Key Challenges

Five key challenges as captured in Table 2-6 were identified and have been described.

System Input Metering unreliable

It was found that many of the water production flows were not accurately measured, and System Input was based partly on flows estimated generally from a treatment works design capacity and hours run. This means that reported NRW levels are unreliable, and comparisons between WSPs, and an analysis of NRW trends over time are not meaningful. Accurate SI metering is crucial to enable WASREB to regulate WSP's effectively and for WSPs to manage NRW to achieve the targets set.

A number of issues were encountered, including meters not working, inaccurate meters, and meters only on the raw water inlet to treatment works (rather than the outlet). Whilst electro-magnetic flow-meters have many advantages in terms of accuracy, low head loss and lack of moving parts requiring maintenance, we recommend that mechanical meters should be used for mains up to 300mm in diameter as they rely on simple technology. Meters should be installed on a straight length of pipe, ideally within the treatment works boundary and should include a strainer to avoid damage from suspended material.

Not all customers metered

In three out of the nine WSPs audited not all customers were metered, although all three were seeking to address this, and metering rates were high. When customers are not metered, there is no incentive to conserve water and flat rate bills may represent a lower equivalent volume than actually used. If most but not all customers are metered this can be viewed as unfair and encourage further wastage.

Customer meters stalled/inaccurate

Over half of customer meters were found to be stalled in some WSPs, and this is likely to be due to the age of meters in most cases or grit or suspended matter in water. Most WSPs were unable to advise on the age of these meters, but believed many to be over ten years old. Stalled meters lead to estimated readings, which in turn can lead to wastage by customers and under-billing. Based on a comparison of bills based on estimated and actual readings, it is assumed that the estimated bills may typically be an under-estimate by 20%. We tested around 20 meters in each WSP in situ, and based on these tests consider the average meter-under-registration to be 2-3%.

Very poor infrastructure

A number of WSPs reported that the mains and service pipelines were old and in poor condition. This is supported by high burst rates and high physical losses in a number of WSPs. Where pipes are in very poor condition, they will require replacement, but this is an expensive solution, and needs to be justified by a reliable assessment of leakage.

Intermittent Supply

Intermittent supply can contribute to deterioration in the level of NRW for a number of reasons, both physical and cultural. Draining and then recharging mains on a regular basis can lead to higher burst rates as significant pressure fluctuations lead to fatigue failure. Intermittent supplies can also lead to customers leaving taps open (to get the supply when it is on), which can lead to wastage and also contribute to NRW if they are not billed on a working meter. When mains are recharged, the customer meters at the end of the system may over read due to air spinning them. These factors combined with poor levels of service can lead to customer dissatisfaction which increases the "legitimacy" of illegal connections and general bad practice.

Table 2-6: Key Challenges

Water Service Provider	Key Challenges				
	System Input meters unreliable	Not all customers metered	Customer meters stalled/ inaccurate	Very poor infrastructure	Intermittent supply
Eldoret		■			
Thika	■		■		
Kakamega	■	■			■
Malindi					
Murang'a South	■			■	■
Embu					
Nakuru Rural	■	■			■
Nanyuki					
Isiolo	■				■

LEGEND ■ Key challenges

2.4. Accuracy of NRW performance data

WSPs provide annual reports to WASREB, and as far as NRW is concerned, these comprise of the annual water production, and annual billed volume. The annual billed volume is the sum of metered and estimated (including flat-rate) billed volumes, it does not involve estimation or interpretation, and it was found that there is no reason to question the total billed volume reported by each of the nine WSPs (this billed volume does however contain inaccuracies and commercial losses which are identified within the water balance).

The annual water production is derived by a number of methods, with varying accuracy. In some cases, it is based on actual meter readings, with meter accuracies ranging typically from better than +/-3% to +/- 20%. In other cases, System Input is estimated based on the design capacity of the production sites accompanied by hours run. The overall accuracy of the derived NRW was assessed based on independent field testing of production meters. The findings are summarised in Table 2-1 and described in more detail in individual findings reports. In summary, of the nine WSPs, high confidence (NRW within +/- 2.5%)was realised in two WSPs, medium confidence in a further two (+/- 10%), and low confidence in five (-10 to +25%).

> "The overall accuracy of the derived NRW was assessed based on independent field testing of production meters"

03 Recommendations

3.1 Addressing challenges

3.1.1. Overview

An action plan for each WSP has been described in the individual findings reports, and these plans are not repeated here. WASREB's NRW management guidelines describe approaches to manage NRW; these have generally been agreed with and have been applied in this audit to derive action plans.

A generic plan has been developed based on the findings from the audits, that provide a framework for implementing the NRW standards in each WSP, recognising the need for a staged and bespoke approach, and this is shown in Figure 3-1. In addition, all the key priorities for action were described, highlighting in particular where technical assistance and funding support from all sector players could be beneficial.

Figure 3-1 Framework for addressing NRW challenges

Task		Indicative timeline (quarters)																			
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
Stage 0. Initial Assessment																					
0.1	Overall audit based on existing data																				
Stage 1 (No Regrets actions)																					
1.1	Establish 100% customer metering																				
1.2	Replace customer meters (>80% working)																				
1.3	Review all disconnected accounts																				
Stage 2 (Improve data and confirm plan)																					
2.1	Accurate System Input metering																				
2.2	Establish Water Balance & monitor																				
2.3	Pilot Area analysis																				
2.4	Establish team																				
Stage 3 (“Quick Wins”)																					
3.1	Implement stakeholder engagement plan																				
3.2	Quick Win: Pressure Management																				
3.3	Quick Wins: Physical Losses																				
2.4	Quick Wins: Commercial Losses																				
2.5	Implement GIS																				
Stage 4 (Create sustainable NRW infrastructure)																					
4.1	Implement DMA																				
4.2	Complete GIS																				
4.3	Meter test bench																				
4.4	Monitor KPIs																				
4.5	Cost benefit analysis																				
Stage 5 (Sustain NRW reductions)																					
4.1	SI meter calibration																				
4.2	Maintain GIS																				
4.3	Targeted mains renewals																				
4.4	Maintain PRVs																				
4.5	Maintain DMA																				
Current status of each WSP																					
Eldoret																					
Thika																					
Kakamega																					
Malindi																					
Murang’a South																					
Embu																					
Nakuru Rural																					
Nanyuki																					
Isiolo																					

- **Stage 0** – In the framework comprises a review along the lines of this audit
- **Stage 1** – "No Regrets" actions for which no further information is required.
- **Stage 2** – Providing reliable data on which to measure NRW and establish the most effective way forward.
- **Stage 3** – To achieve some "Quick Wins" that will both reduce losses and improve levels of service.
- **Stage 4** – The WSP should establish the infrastructure (in particular, continuously monitored DMA)

Stage 0 in the framework comprises a review along the lines of this audit, and this is therefore complete for all of the nine WSPs. Stage 1 comprises "No Regrets" actions for which no further information is required. This entails making sure that all customers are metered (and meters are reliable), and ensuring the more obvious illegal connections are addressed (ensuring disconnected accounts have not become illegal connections).

Stage 2 entails providing reliable data on which to measure NRW and establish the most effective way forward. The key components are to establish effective SI monitoring and derive a Water Balance (that should identify key components as well as the overall NRW). In some cases, analysis of a pilot area would be beneficial, but this may be based on the work undertaken under this project in some cases. Regular monthly NRW reporting should be established.

The aim under Stage 3 is to achieve some "Quick Wins" that will both reduce losses and improve levels of service. The nature of these will depend on the WSP (for example, pressure management is not appropriate in all), and include addressing some key problems.

Under stage 4, the WSP should establish the infrastructure (in particular, continuously monitored DMA) to enable it to monitor and manage NRW (and physical losses in particular) on an ongoing basis. Once this has been established, ongoing effort will be required to further reduce or maintain NRW at the target level.

3.1.2. Priorities for each WSP

Whilst a number of features are common to all nine of the WSPs audited, each one is different. This section, identifies the current priorities to move towards effective NRW management, particularly those where external support may be beneficial.

Eldoret

In Eldoret, most customers (99%) are metered, and completing the metering programme is a priority, as is the installation of an accurate production meter at Sosiani treatment works. ELDOWAS has started to implement DMA, and it is considered that ongoing technical assistance in the implementation of DMA would be beneficial to make this effective going forward.

Thika

Whilst NRW appears under control in THIWASCO, the new SI meters at the treatment works are inaccurate, and hence confidence in the NRW figure is low. Replacing these meters, or getting them to work accurately is therefore a priority. In addition, 55% of consumption is based on estimated readings and many customer meters should be replaced. Further priorities should only be determined once these two actions have been completed.

Kakamega

In Kakamega, about 95% of the customers are metered, and completing the metering programme is a priority, as is the installation of accurate production meters at Tindinyo and Nambacha treatment works. Technical assistance to establish effective records and reporting, as well as the implementation of DMA, is needed to enable KACWASCO to monitor and then manage NRW effectively.

Malindi

In Malindi, MAWASCO appear to have commercial losses under control, and the key priority now is to address physical losses. Technical assistance to

establish and then monitor DMA in conjunction with the completion of GIS and then develop an effective leakage control team is needed to enable MAWASCO to monitor and then manage NRW effectively.

Murang'a South

MUSWASCO faces significant challenges, including a high number of disconnected accounts, high leakage and poor infrastructure. Installing accurate production meters at Ichichi and Kinyonya are priorities. The pilot project in Kanyir-ini delivered good results, reducing NRW from 80% to 53% in six months by addressing both physical and commercial losses. Given the critical situation in Murang'a South, there is an urgent need to implement similar initiatives with technical assistance and capacity building support across MUSWASCO.

Embu

EWASCO was one of the WSPs covered by the JICA funded NRW standards project in 2011, and some of benefits of that project can still be observed. However, the work has not been built upon, and in some cases NRW management has taken a backwards step (NRW increased from 35% in 2011 to 50% in 2016, and the NRW team was disbanded). EWASCO need to create a dedicated NRW team, and roll out some of the findings (for example pressure management) from the JICA-funded project.

Nakuru Rural

In NARUWASCO, most of the customers are unmetered (73%), and completing the metering programme is a priority, as is the replacement of 40% of the existing meters that are not working. Installation of accurate production meters at Rongai and Turasha treatment works is needed to establish an accurate water balance. The illegal connections team should be strengthened, and illegal use addressed in conjunction with the metering and meter replacement programmes.

Nanyuki

NAWASCO appear to have good measures in place to address NRW. The focus now should be to address physical losses, by ensuring DMA function correctly, implementing pressure management where possible, and establishing a leak detection and repair team. Focussed Technical Assistance may be required to optimise DMA and implement pressure management.

Isiolo

IWASCO should renew the production meter at the new treatment works in order to provide a reliable measure of NRW. The Kulamawe DMA is working well, and IWASCO should build on this to establish other DMAs, create a leakage detection and repair team, and drive down physical losses. Focussed Technical Assistance may be required to make this effective.

3.1.3. NRW management support nationally

Figure 3-1 shows the proposed technical framework for managing NRW, and whilst it is based on our findings from nine WSPs, they represent a diverse range, and the framework should therefore be applicable at a national level. The water sector in Kenya has received significant support, and made some progress in addressing NRW, but levels are still unacceptably high.

Technical Assistance

It was observed that a number of cases where Technical Assistance (TA) was provided, it delivered benefits, for example the JICA-funded project in Embu, and WASPA support in Isiolo. However, it appeared that benefits were often realised but not then rolled out on a wider basis across the WSP. TA should continue (and make use of local organisations such as WASPA and KEWI), and could be improved by providing ongoing projects (but reducing support) to enable benefits to be sustained and realised beyond the area in which TA directly supports. To make TA effective, the WSP needs to establish a team that will benefit from the training, and then continue to apply what's learnt on an ongoing basis so as to institutionalise that capacity.

Examples have been seen where one WSP shares experience and skills with others, and this can be a very effective means of sharing best practice. This can be achieved through forums where representatives share experience, by secondments, staff rotation, or short stints where a team from one WSP supports another for a defined task. Such measures are highly recommended and they should be continued and strengthened.

Regulation

Effective regulation requires accurate information, and the setting of realistic but challenging targets. The level of confidence in reported NRW was low in five of the nine audited WSPs (see Section 2.4), due to the quality of system input data. Reliable and accurate production meters should be installed as a matter of priority to enable effective comparison, and then setting verifiable NRW reduction targets for WSPs. Further details are provided in Section 2.3.

There do not appear to be good incentives and sanctions for WSPs to provide accurate information, or to achieve NRW reduction targets. An appropriate incentive and sanction could motivate WSPs to improve data quality and drive NRW levels down.

Organisation within WSPs

In order to maintain NRW at relatively acceptable level (let alone reduce it), continued consistent focus and effort is required. To achieve this, responsibility needs to be assigned to fairly senior individuals at the WSPs supported by stable and

consistent teams who will effectively monitor and drive NRW levels down to target. It is imperative that high level NRW objectives are cascaded throughout the organisation, and this means NRW targets need to be owned at the highest level within the WSP i.e. management goodwill, commitment and support.

Stakeholder engagement

High levels of NRW contribute to poor levels of service affecting both availability of supply and water pressure. WSPs have some responsibility to engage with customers to highlight the need to reduce wastage and its impact on service. This could be strengthened by a national campaign, which could be better resourced. An example was also noted of water provided in bulk without charge from Murang'a South WSP to Maragua area under a different WSP.

3.2. Recommended updates to WASREB's NRW management guidelines

An initial review of the Standards for Non-Revenue Water Management in Kenya was carried out, and it was concluded that they were generally a good guide for NRW reduction in Kenya. The manual was also reviewed in light of the findings from this audit, and it was concluded that the NRW standards remain a good basis for NRW management overall. There are some comments provided on particular sections of the NRW manual in sequencing of NRW improvement measures.

Table 3-1 highlights some overall comments on the Standards.

Repairs

The NRW Standards highlight the importance of quality of construction, but not quality of leak repairs. This is an important consideration in addressing physical losses, and we recommend that effective repair techniques (covering aspects such as workmanship, materials, stores, and training) should be covered.

Cost Benefit Analysis

Whilst cost benefit analysis (CBA) is important, there are instances where "No Regrets" NRW reduction measures should be implemented before CBA is undertaken. In addition, it is important that findings from pilot areas are viewed with caution in case they do not represent the overall WSP.

Stakeholder Engagement

The NRW Standards do not mention engagement with customers in any detail. Whilst reducing customer wastage is not strictly NRW, raising the profile of the need for water efficiency in conjunction with reporting leakages, illegal use and highlighting the reasons to pay for water and reduce losses are an effective means of improving the supply/demand balance. This would be a useful addition to the Standards.

Sequencing of NRW improvement measures

The Standards describe clearly the approaches to be applied to address commercial and physical losses, and outline an approach which is similar to the framework described above. There is however little recognition that different WSPs will be always at different levels of maturity, and it's a framework of measures (along the lines of Figure 3-1) that recognises that the starting point in any WSP may not be stage 1 and would be a useful addition.

Training

The Standards do not specifically highlight the need for regular training, both in reporting and leakage detection and in leakage repairs. In a number of WSPs, there were examples of effective technical assistance, but the full benefits of this were not being sustained. Ongoing refresher training would be a means to improve this.

Maturity Assessment

Section 12.3 of the NRW manual includes a section to prioritise an implementation plan for NRW reduction. It would be beneficial to include in the NRW Standards a maturity assessment similar to the one described by this report to enable WSPs to assess their current position against a defined benchmark.

Table 3-1: Review of NRW Standards

Section	Comment/Recommendation
Section 1.3.	A further knock-on benefit of NRW reduction is that it can improve service levels which in turn can improve engagement with customers and their willingness to pay for the water service.
Section 1.4.	Under point 3, high NRW also contributes to insufficient water. Further, not all customers are metered in all WSPs, and many customer meters are old and stalled or unreadable. Quality of repairs as well as construction contributes to high NRW.
Section 2.1	As noted in Section 2, we recommend that mechanical meters with strainers should be used for mains up to 300mm diameter; we consider the meters (if correctly installed) to be sufficiently accurate, and our experience in the field testing exercise was the more sophisticated meters can be unreliable.
Section 2.3	Digitising the location of customer meters in GIS should also be a priority as it assists in identifying illegal connections.
Table 2.2	We would recommend that average repair times, and the proportion of reported and detected leaks should be recorded.
Table 3.2	We would recommend that pressure management should be the first choice on intervention as it can be implemented quickly and is cost effective.
Section 4.2.2	We would recommend that GIS should be mentioned as a tool to assist in identifying illegal connections.

Appendix A
Water Balance Training

Water Balance training was provided as part of the fieldwork to WSP staff.

Howard Humphreys
an Atkins company

Having worked together in Africa for over 15 years, HH is now formally part of Atkins, a member of the SNC-Lavalin Group.

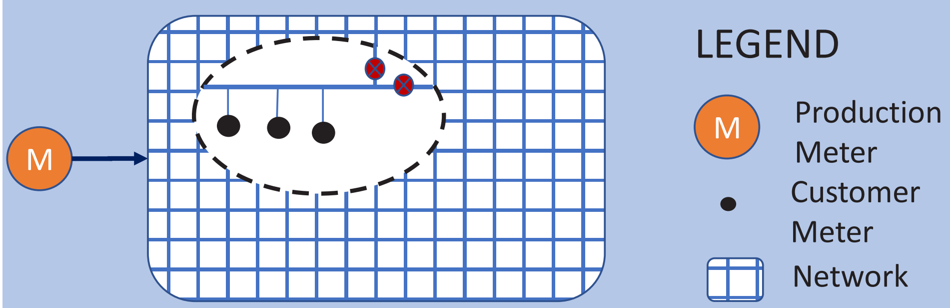
NRW Audit of 9 WSPs: Water Balance Training

What is a Water Balance?

The Water Balance provides an estimate of Non-Revenue Water (NRW), split into components such as physical leakage and illegal use.

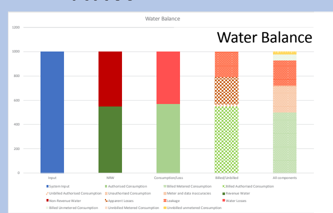
Why do a Water Balance?

It provides a means of assessing and comparing NRW performance, but also identifies areas to focus on to reduce losses in an effective manner. For example, should the focus be leakage or illegal use?



NRW = System Input (from Production meters) – Water Billed (Sum of customer meter readings plus other billed unmetered)

NRW



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Components of the Water Balance - Input

HINTS

- (M) Sum of Production Meters
  - Sum of monthly meter reads
  - Estimated readings

Likely to be zero

An estimate (but a low value)

Based on illegal connection assessments

Based on customer meter checks from this project

Derived from the above

Seven items of data 1.0 and 2.1-2.6 needed for the period in question (typically annual figures built up from monthly data)

No.	Description	Remarks	Value	Units	Error (%)
1.0	System Input	Sum of production meter readings minus exports for period	1000	m^3	2%
2.1	Metered consumption	Sum of customer meter readings for period	500	m^3	
2.2	Unmetered consumption	Sum of estimated readings due to no meter or stalled meter	0	m^3	0%
2.3	Unbilled metered consumption	Sum of metered consumption not billed eg. Municipalities	0	m^3	0%
2.4	Unbilled unmetered consumption	Sum of unmetered consumption not billed eg. Fire Brigade use, flushing	20	m^3	50%
2.5	Unauthorized Consumption	Illegal use	216	m^3	10%
2.6	Meter and data inaccuracies	Meter under-registration and billing errors	5	m^3	10%
2.7	Physical Losses	Leakage	259	m^3	

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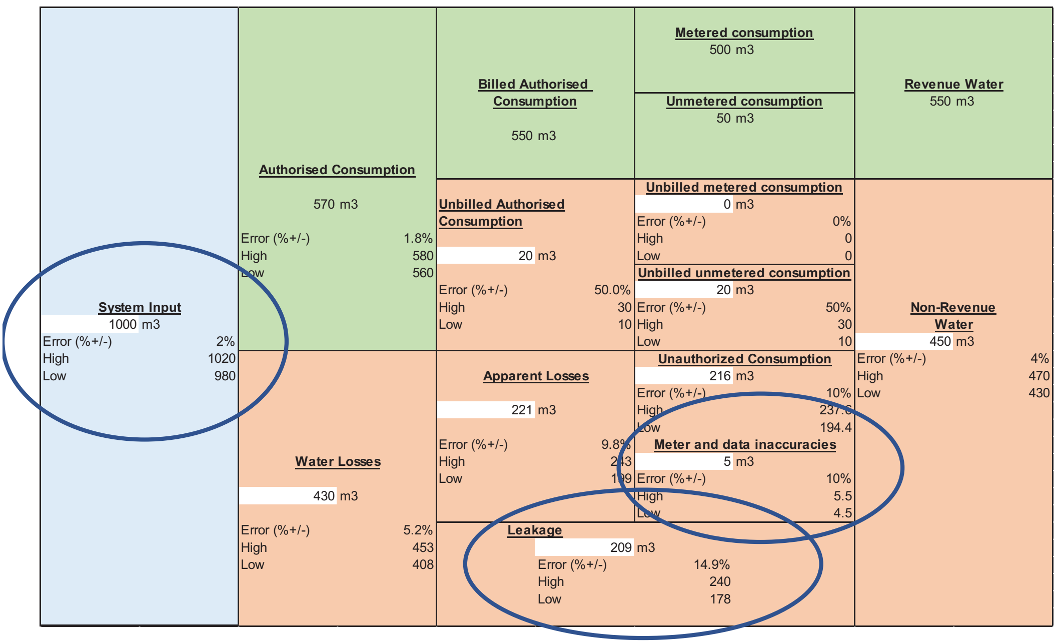
Components of the Water Balance - Output

The field work under this Project will improve the confidence in:-

System Input: Production meter checks and measurements will improve the accuracy of System Input figures.

Meter under-registration: Customer meter checks in situ will improve the estimation of meter errors (assumed to be under-registration)

Leakage: The measurement of nightflow in pilot areas will provide a better assessment of the physical losses (at night consumption is low, so the minimum flow represents mainly leakage).



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Components of the Water Balance - Graph

In this example we can see:-
NRW: Is about 45%

The main components of NRW are:

- Illegal use
- Physical leakage

This suggests the focus in this area should be:-

- Addressing illegal connections;
- Locating and repairing physical leaks.

(Meter and data inaccuracies do not appear an issue in this case)


AVAILABLE UP TO 630MM

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