NON-REVENUE WATER ASSESSMENT STRATEGY FOR THE UMZINTO WATER SUPPLY SCHEME: TOWARDS GREEN ECONOMY

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Abstract
Huge infrastructure investment is imperative for the collection, treatment and distribution of potable water. Prior to further investment into the production of potable water, more emphasis should be placed on utilizing the available resources. One of the major drawbacks in achieving a green economy in the water sector is the significant losses in potable water which are incurred after having invested substantially in its production. If the current global trends continue, water demand is estimated to exceed supply by 40% within the next 20 years. This is an alarming situation when compared to the estimated 25-40% loss of this resource in developed countries and is worse in developing countries.

In this study, a strategy for assessing and reducing Non-Revenue Water (NRW) in the Umzinto Water Supply Scheme (UWSS) was developed. The water supply scheme consisted of Pennington, Umzinto, Umzinto Flats, Ghandinagar, Shayamoya, Park Rynie, Scottburg South, Scottburg Central, Amandawe, Malangeni, Amahlwonga and Imfume. The first eight areas are urban supply zones while the last four are rural zones. The method employed in the assessment was a combination of the top-down and component-based approach. A few modifications were allowed for, to enable the calculation of NRW component as advised in the Standard South African Water Balance. Results of the NRW assessment for UWSS showed that Real Losses were a dominant component. As percentages of NRW, the components consisted of 65% Real Losses, 32% Apparent Losses and 3% Unbilled Authorised consumption. The NRW itself was 28% of the System’s Input Volume. From the assessment, a strategy that would help reduce the NRW was developed and coupled with this, is a discussion of how the strategy could contribute towards developing the green economy.
Introduction

The primary goal of most drinking water treatment plants is to provide potable water to consumers. This is a complex process as it should not only be governed by the water quality and quantity. Consideration should also be given to the great investment required for the infrastructure to collect, treat and distribute water. Instead of just increasing investment in the production of potable water, greater focus needs to be put into utilising the available resources. This is where the concept of green economy comes in the water sector where emphasis is that every drop of potable water should be accounted for. According to the current global trends, water demand is estimated to exceed supply by 40% within the next 20 years (Hoekstra, 2013, Olsson, 2015). This is an alarming situation when compared to the estimated 25-40% loss of this resource in developed countries and is worse in developing countries.

In this study, instead of just looking at water loss, Non-Revenue Water (NRW) is also considered. NRW is a better component of measure as it considers the financial aspects of the water distribution system. Mutikanga et al. (2011), defined NRW as the difference between system input volume and billed authorized consumption. Work by Wyatt and Romeo (2011) described NRW as comprising of physical losses and commercial losses. Physical losses are made up of pipe bursting and leakages while commercial losses are a result of illegal connections, unmetered public stand pipes, meter error and data recording errors.

The global NRW level is estimated to be at 35%. (Farley et al., 2008, Bhagwan et al., 2014). Further, the global volume of NRW is 48.6 Billion Cubic Meter (BCM) per year of which 32.7 BCM is real (physical) losses (Kingdom et al., 2006, Aalto, 2014). In addition to this amount of water wastage, water utilities incur costs as high as US$14 billion a year in producing the water that is lost as NRW. If half of this amount was saved, it would be enough to provide water service to an additional 100 million people without further investments (Kingdom et al., 2006, Farley et al., 2008).

It should be noted that there has been great achievements in the development of both technical strategies (pressure management, flow monitoring) and operational management to reduce physical losses by developed countries. However, developing countries have faced great difficulties in implementing these strategies. Poor infrastructure, equipment that have been unmaintained for long periods, high unbilled water through fraud and illegal connection have been cited as the major contributors to their challenge (Liemberger et al., 2007, Frauendorfer and Liemberger, 2010).

Langa and Quessouji (2007) raised the issue of poor equipment and technologies in developing countries with the example of Maputo. The lack of flow meters or their non-accuracy prevent a good knowledge of the networks and make difficult the establishment of a precise water balance and therefore action plans. The authors emphasized the fact that in their attempt to assess the water losses in Maputo, most of the values were uncertain or based on estimated data that prevented them to make any reliable conclusions on volumes lost or any recommendations to tackle the losses. Furthermore, they also missed data on the network by itself due to poor installation conditions, and illegal connections. Their recom
mendation under such circumstances was installation of monitoring equipment and the conduct of surveys on physical and commercial data (Langa and Quessouji, 2007).

Gumbo and Van der Zaag (2002) experienced the same difficulties in evaluating the water balance of the Mutare water supply system in Zimbabwe due to non-working bulk meters or the absence of meters, especially for big consumers such as industries. They also brought to the fore the role of political constraints that influence the prioritisation of objectives, choice of projects and allocation of budgets. They noted the need to assess water losses and ways of reducing such losses before embarking on expensive engineering projects to increase the volume of water supplied (Gumbo and Van der Zaag, 2002). This case illustrates the role played by external pressure from politicians and funders and underlines the complexity of water projects and the need for strong leadership.

In contrast, Mahmoudi (2007) revealed the positive role played by the Iranian government in addressing NRW by putting pressure on the water and wastewater companies to allocate part of their budget to this task. This led to improved water loss management through better operational practices (leakage detection and quicker responses to detection, replacements and the implementation of new monitoring equipment) in line with national standards whilst installing new branches and conducting pilot projects (Mahmoudi, 2007).

Ndokosho et al. (2007) examined the relationship between a public utility and the government in Namibia. The government sets overall objectives, such as full recovery cost, but the “Board of Directors” defines specific targets and formulates policies to achieve these objectives. While the water utilities are generally not totally free to implement new policies as they generally do not have sole authority to set tariffs, this governance system aims to reduce political influence (Ndokosho et al., 2007). In this study NRW assessment in the Umzinto Water Supply Scheme (UWSS) was conducted and discussion on a strategy reduction is given.

**Study Area**

The UWSS is located in the Umdoni Local Municipality and it falls in the Ugu District Municipality. The supply scheme consists of Pennington, Umzinto, Umzinto Flats, Gandinagar, Shayamoya, Park Rynie, Scottburgh South, Scottburgh Central, Amandawe, Malangeni, Amahlongwa and Imfume. The first eight areas are urban supply zones while the last four are rural supply zones.

The components of NRW in the UWSS will generally include those in the South African Water Balance. The components are:

- Unpaid Water Bills (non-recovered revenue);
- Unbilled metered consumption (authorised consumption);
- Unbilled unmetered consumption (authorised consumption);
- Unauthorised consumption (apparent losses);
- Customer meter inaccuracies (apparent losses);
- Leakage on transmission and distribution mains (real losses);
- Leakage on overflows at storage tanks (real losses); and
- Leakage on service connections up to the point of customer meter (real losses).
Unpaid Water Bills
This is usually a result of bad debts in the water sector. The consumer would have been billed but eventually they fail to pay their bills. This water will exclude the 6Kl/month free basic water that is given to every household in South Africa. The data can only be obtained from the financial department at the Ugu District Municipality.

Unbilled Metered Consumption
These include the water being used in municipal buildings, parks and swimming pools. Another component here will be unreadable consumer meters.

Unbilled Unmetered Consumption
This authorised component of unbilled water comes from consumers that are billed on a flat rate. The component adds to NRW when the actual consumption is far much more than the flat rate amount. In some cases consumers who are billed actually take advantage of this arrangement. In low income areas, stand pipes are enacted. Users of the standpipes do not pay for the water and hence it is a major contributor to the unbilled metered consumption. With most stand pipes being unmetered, the volume of water is often estimated and included in the water balance. Major losses through the stand pipes occur due to vandalism and lack of maintenance. The most common criteria is a spindle that has been removed from a tap and the water just runs.

Adding to the unbilled unmetered consumption is the use of fire hydrants. Most fire hydrants are unmetered and are subsequently subject to abuse from consumers through illegal connection. In some cases, taxi drivers can use the hydrants to wash their vehicles. Beside these illegal activities, the volume of this portion of unmetered consumption will also include the water lost when the hydrants are opened to reduce pressure in the distribution system before maintenance.

Unauthorised Connection
Like any other municipality, Ugu District Municipality also has to deal with problems of illegal connections. In South Africa, water connections are deemed illegal when the consumer connects directly to the water source without the consent of the municipalities. The most common forms of unauthorised connections involve the by-passing of meters and connecting on to air valves.

Customer Meter Inaccuracies
With time, customer meters lose their accuracies. The accuracy of the meter is also dependent on the water quality. In the UWSS, age is the main determinant of meter accuracy. This is a very difficult component to estimate volume of water that has been lost through an inaccurate meter.

Leakage on Transmission and Distribution Mains
When there is excessive pressure, mains can burst and this can be a significant contributor to real losses in the UWSS. Another component from the mains is the background leaks. To control these two sources of loss, the municipality has a pressure management programme and invests into the maintenance of the distribution system. Community awareness programmes are run to help the consumers understand their role in reducing water loss. This is very essential for the municipality to reduce or eliminate unreported leaks. When consumers are not educated about the importance of reporting water leaks they will not do so unless their household taps run dry.
Leakage and Overflows at Storage Tanks
The municipality has a good reservoir balance system to avoid these leakages. The system will contain meters, valves and control systems at the reservoirs. Although water losses cannot be reduced to zero, this type of water loss is very minor in the UWSS.

Leakage on Service Connections up to the Point of Customer Meter
In most systems, leakage from connections is by far the greatest source of physical leakage; often 80% or more of the total physical losses. A portion of the service connection leakage also contributes to the unavoidable annual real losses. The total volume of water lost as a result of this leakage is therefore dependant mainly on the number of service connections within a system and the average operating pressure.

Methods
The method employed in the assessment was a combination of the top down and component based approach. A few modifications were allowed to enable the calculation of NRW components as advised in the Standard South African Water Balance. This is because the top-down, bottom-up or the component based approach were seen to be inappropriate for the UWSS unless they were modified or combined. The top-down approach makes an assumption on the input volume that lead to underestimation of apparent losses.

The approach assumes that the unauthorised consumption will be at least 0.25% to 1% of the input volume. Liemberger et al. (2007) show that the bottom approach can be applied to distribution systems that meet particular hydraulic conditions. This makes it difficult to apply it on the UWSS.

The limitation for the third method is its well-known uncertainty. The component based analysis is data driven hence its accuracy will be depended on the accuracy and completeness of the data. For the UWSS, some values are estimated hence it affects the accuracy. To mitigate this, it is usually not encouraged to use this approach on its own.

Evaluation Steps
The first step was to determine the NRW by subtracting the volume of billed water for the UWSS from the volume of the water produced by the Umzinto water treatment plant. The next step involved the calculation of the NRW components. The evaluation steps are illustrated in Figure 1.

Figure 1 Steps involved in the calculation of NRW of the UWSS

- Determining volume of NRW
- Estimate Unbilled Authorized Consumption
- Compute Real Losses
- Calculating Apparent Losses
**Determining volume of NRW**

It should be noted that the time period of the billing month does not coincide with that of the production month. The meters also will have some inaccuracies. This means before the NRW is determined, adjustments should be done to account for these. The produced water volume was obtained from the SIV data reading and adjustments were made to account for the inaccuracies. The volume of the billed consumption is obtained for both the metered and unmetered connections. After correcting the time, the adjusted NRW volume is obtained.

Adjusted NRW = Adjusted Produced Water – Adjusted Billed Water

Figure 2 shows the general framework to be taken in determining the NRW. AWWA (2009) recommends a period of at least one year for assessing the NRW levels. This makes it possible to take into consideration the seasonal variations. In this study the data used was for the year period ending December 2013. The system input volume (produced water) was adjusted for production meter inaccuracies. Since it is not possible for the time frame of this study to conduct accuracy analysis and experiments for the production meters, the production meter inaccuracy was assumed at 7% under-registration based on the estimation of the production unit in Umzinto water utility. This estimation is justified by the following:

- There is no maintenance programmed for production meters. The production meters are examined or maintained only once they have stopped working or when readings being obtained from them are too low.
- Some meters are not installed according to their manuals that require minimum straight distance before water meter or specified sizes of pipe diameters.
Billed Metered and Unmetered Consumption

Metered consumption and the estimated unmetered consumption of customers with flat rate policy were obtained from the billing records of Umzinto water utility. Then the billed water (metered and unmetered) was summed.

Lag Time Adjustment

For the reason that water produced in Umzinto water utility is billed after a month, the production data were taken for all the months of the in 2013 except January 2013. Instead, the billed consumption for January 2014 was counted to represent the consumption of December 2013. Other time lag adjustments were neglected. After all adjustments, NRW volume was determined by subtracting the adjusted volume of billed water from the adjusted volume of produced water.

Estimating Unbilled Authorized Consumption

Unbilled authorized consumption has two types; metered and unmetered. The unbilled metered consumption in the UWSS consists of the consumption of the staff in buildings belonging to the utility as they are metered. The unbilled unmetered consumption in Umzinto water utility consists of water used for pipes washing, fire-fighting, special institutions, and consumption of some notable people. All these types are supplied by means of water tankers, and thus estimated by the number of the tankers per year for each type in every administrative zone. The unbilled authorized consumption (metered and unmetered) was estimated by obtaining relevant data from the internal reports of the utility.

Calculating Real and Apparent Losses

As the apparent losses are defined and the unbilled authorized consumption is estimated, then real losses could be calculated straight forward from the following formula:

\[
\text{Real Losses} = \text{NRW} - \text{Apparent Losses} - \text{Unbilled authorized consumption}
\]

Results

Results of the NRW assessment for UWSS showed that Real Losses were a dominant component. The NRW components consisted of 65% Real Losses, 32% Apparent Losses and 3% Unbilled Authorised consumption. The NRW itself was 28% of the System’s Input Volume.

Percentage of NRW in the System input Volume

NRW in the UWSS makes up 28.1% of system input volume and these amounts to 5017 Kl/day. Table 1 shows the volume of NRW, the volume of billed water, and the adjusted volume of produced water with consideration to time lag adjustment in the period starting July 2013 to June 2014. Figure 3 illustrates the percentage of NRW in the System Input Volume.
Table 1: Volume of NRW in the UWSS for the year ending in June 2014

<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>System Input Volume (Kl/day)</td>
<td>5017</td>
</tr>
<tr>
<td>Billed Water (%)</td>
<td>72</td>
</tr>
<tr>
<td>Non-Revenue Water (%)</td>
<td>28</td>
</tr>
<tr>
<td>Apparent Loss (%)</td>
<td>9</td>
</tr>
<tr>
<td>Real Losses (%)</td>
<td>18</td>
</tr>
<tr>
<td>Unbilled Authorised Consumption (%)</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2: Volumes of metered and unmetered unbilled authorized consumption for the year ending June 2014

<table>
<thead>
<tr>
<th>Produced Water (Kl/year)</th>
<th>Total Billed Water (Kl/year)</th>
<th>NRW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td>6193651</td>
<td>Metered 4285185 Kl/year</td>
</tr>
<tr>
<td>Adjusted for Meter Accuracies</td>
<td>325981</td>
<td>Unmetered 403387 Kl/day</td>
</tr>
<tr>
<td>Total</td>
<td>6519632</td>
<td>Total 4688572 % of system input volume 28.1</td>
</tr>
</tbody>
</table>

Figure 3 Percentage of NRW in the System Input Volume.
Components of Authorised consumption

Authorised consumption consisted of metered and unmetered, billed and unbilled consumption. Table 2 shows that for the year 2014, the total volume of unbilled authorized consumption was 68364 Kl/year which made up 1% of the system input volume. Figure 4 shows the components of consumption in the UWSS.

Figure 4: Components of Authorised consumption for the UWSS

Table 3: Volume of Apparent and Real Losses in the UWSS

<table>
<thead>
<tr>
<th></th>
<th>Apparent Losses</th>
<th>Real Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kl/year</td>
<td>580598</td>
<td>1182098</td>
</tr>
<tr>
<td>Kl/day</td>
<td>1591</td>
<td>3238</td>
</tr>
<tr>
<td>% of System input Volume</td>
<td>9</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 4: Components of NRW in the UWSS

<table>
<thead>
<tr>
<th>Metered (Kl/Year)</th>
<th>Unmetered (Kl/Year)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Billing Database Shortfall</td>
<td>Municipal use, Fire water, and Flushing of Pipes and Reservoirs</td>
<td>3072 Kl/year</td>
</tr>
</tbody>
</table>
Components of NRW Breakdown

Table 5 shows the System Input Volume, its components are Billed Water and NRW. It also shows three components of NRW as percentages of System Input Volume. Figure 5 shows that Real Losses are the dominant component of NRW making up 65% of NRW and 18% of the System Input Volume. Apparent Losses make up 9% of System Input Volume and stand for 32% of NRW volume as shown in Figure 5. Unbilled authorized consumption make up 1% of the System Input Volume.

Figure 5: Components of NRW in the UWSS

Water Balance for UWSS

Table 5 illustrates the final results of NRW assessment for the UWSS in Kl/year. The water balance is different from the Standard South African Water Balance in the sense that the free basic water is taken as a component of the billed authorised consumption.

Table 5 Water Balance for the UWSS in kl/year

<table>
<thead>
<tr>
<th>System Input Volume 6 519 632 kl/year</th>
<th>Authorised Consumption 4 756 936 kl/year</th>
<th>Billed Authorised Consumption 4 688 572 kl/year</th>
<th>Exported Water 71 547 kl/year</th>
<th>Potential Revenue Water 4 688 572 kl/month</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Billed Metered Consumption 4 285 185 kl/year</td>
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<td></td>
<td></td>
<td></td>
<td>Free Basic Water (Standpipes) 331 840 kl/year</td>
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<td></td>
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<td></td>
<td>Unbilled Authorised Consumption 68 364 kl/year</td>
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<td></td>
<td></td>
<td></td>
<td>Unbilled Unmetered Consumption 3 072 kl/year</td>
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<td></td>
<td></td>
<td></td>
<td>Unbilled Metered Consumption 65 292 kl/year</td>
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<td></td>
<td></td>
<td></td>
<td>Non-Revenue Water 1 831 060 kl/year</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Water Losses 1 762 696 kl/year</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Apparent Losses 580 598 kl/year</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Unauthorised Consumption 430 616 kl/year</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Metering Inaccuracies 149 981 kl/year</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Real Losses 1 182 098 kl/year</td>
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<td></td>
<td></td>
<td></td>
<td>Mains and Distribution Leaks 969 321 kl/year</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Reservoir Overflows 5 910 kl/year</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Service Connection Leaks 206 867 kl/year</td>
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</tbody>
</table>
Discussion
When developing a NRW strategy for any water network it is crucial to put focus in its design and introduction. A review should be conducted to gain a full understanding of the network’s behaviour and operation. From water audits such as NRW assessment, the levels of water losses should be quantified. For example the NRW assessment for Umzinto showed that Real Losses were high. This is what should inform the setting targets and dividing them between short and long term. A good strategy would consist of an appropriate mix of NRW reduction activities combatting the different causes of water loss.

In the planning and design stage, a NRW strategy should stipulate ways of dealing with the inadequate background data in the supply schemes/systems. This is a major challenge for small water supply schemes and was a major contributor in the selection of a method to assess NRW for the UWSS. Baseline field measurements such as flow (System Input Volume and Minimum Night Flows) and pressure should be reliably set. In addition there should be a centralised (and electronic) information database to facilitate research and data analysis. The most important aspect of a NRW strategy is to clearly stipulate its purpose. For example, a strategy can be developed to reduce water losses to an acceptable or economic level and to improve performance. In some case it can include or just involve the maintenance improvements gained.

NRW strategies should be developed with the aim of improving sustainability in water supply schemes. This can only be achieved if the financial components involved are fully considered. In a supply, an economic level of leakage should be set. This defines the relationship between cost of saving water and its value (Lim et al., 2015). It is evident that more support would be given to a strategy in which the cost of saving water is lower than its value. A plan to sustain the cash flow during the strategy implementation should be in place as some of the activities such as customer meter replacement can have long payback periods of at least one year. It will be very important for any water utility to make sure that all the advances and improvements that are made in introducing the water loss strategy are sustained. This involves the following activities:

- Ensuring appropriate staffing levels
- Staff education and training
- Operation and Maintenance
- Assessing and monitoring performance

Conclusion
Evaluation of NRW is an integral phase of designing a management strategy to reduce and control water losses in a distribution system. This is important to ensure that the greatest possible percentage of water treated by a treatment plant reaches the consumer and is turned into revenue. The process can be demanding and data consuming. To make it efficient there is need to prioritise components of NRW in a water distribution system. This study assessed NRW components for UWSS and suggest an approach which water utilities could use to breakdown NRW and efficiently draw up water balances.
NRW consisted of 65% Real losses, 32% apparent losses and 3% Unbilled Authorised consumption and it was concluded that Real losses are a dominant component of NRW for UWSS.

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