Assessment of water loss in Harare, Zimbabwe
Michael Gregory Ndunguru and Zvikomborero Hoko

ABSTRACT

A major challenge facing water utilities is the high level of water losses, which affects the financial viability and adequacy of water in the system. A study was carried out from January to May 2012 to characterize water losses in selected areas of Harare, Zimbabwe. Assessment of the contribution of water leakage to total water loss was carried out through water audits in four selected suburbs. Minimum night flows were determined over a number of days, and the SANFLOW model was used to determine average real losses. The water loss expressed as a percentage of supply in the four suburbs ranged from 29 to 43%, and was above the level expected for well-performing utilities in developing countries of 23%. Leakage contributed most to the water loss (>70%). For the entire city, the study established that non-revenue water ranged from 43 to 74% over the period 2009–2011. The study concludes that water loss management in Harare is poor, and this is affecting the quality of service delivery. There is a need for Harare to take a more proactive approach to water loss management, including periodic water audits.

Key words | Harare, real losses, water audits, water leakage, water loss

INTRODUCTION

Globally, water demand is rising and available water resources per capita are diminishing, mainly as a result of rapid population growth and urbanization. Almost all of this growth is occurring in urban areas of developing countries. These pressures highlight the need for a paradigm shift to utilize water resources as efficiently as possible. Without effective actions, the available water resources per capita will be diminishing even faster in the future due to increasing population. It is estimated that by 2025, the total water demand in developing countries will increase by 27% compared to the demand in 1995 (Rosegrant et al. 2002).

Water loss is a problem for almost all water utilities in the world (Kingdom et al. 2006). Public water utilities have failed to provide customers with adequate water supply due to many factors, including high water losses in the distribution systems (Baietti et al. 2006). Water losses in the distribution systems worldwide range from 15 to 60% of the total water supply (Balkaran & Wyke 2002). This problem takes a new dimension in developing countries, where a combination of ageing infrastructure, intermittent supplies and illegal use worsen the problem (Rizzo 2000). Problems facing most developing countries including Zimbabwe are often associated with poor infrastructure. Most of the water utilities suffer from water leakage in their distribution systems, thus making it difficult to provide sufficient water to the customers on a timely basis (Kleppen 2011). On the other hand, high water losses in water systems contribute to the non-revenue water problem being faced by water utilities (GWI 2009). However, these unused and wasted resources are already treated to drinking water standards and energized to provide adequate pressure to reach the consumers. The World Bank recommends non-revenue water of less than 23% (Tynan & Kingdom 2002), while 20% was suggested for well-performing urban water utilities in the Southern Africa Region (Gumbo 2004).

Harare Water is mandated to supply potable water to the population of Harare City and its satellite towns. It is also responsible for wastewater management within the...
jurisdiction of the Harare City Council. Harare Water was formerly the Water and Sanitation Department of the City of Harare, and is still under the Harare City Council. There are plans to eventually turn it into an autonomous utility. Provision of an adequate water supply is a major challenge for Harare Water (City of Harare 2011). Additional sources of water are becoming more difficult and expensive to exploit, and there is a substantial investment needed to treat the water into a product suitable for human consumption. A plan to augment the water supply for Harare by construction of a dam and water works (the Kunzwi Water Supply Project) some 70 km away from the city has failed to materialize since the early 1990s due to funding limitations.

There is lack of knowledge about the contribution of water leakage to the water losses in Harare Water at present. The last leakage detection study was carried out around 1996/7 and concentrated on the central business district (CBD). Currently, the utility is reporting a high level of non-revenue water ranging from 57 to 60% of water produced per annum (City of Harare 2011). However this water loss is not based on a comprehensive assessment of the water losses in the water distribution system. It is believed that major contributing factors include high physical losses and a significant portion of the customers not being in the database. These high percentages of water loss have continued to affect water service delivery in the city. There is therefore a need to understand and quantify the contribution of water leakage to water losses, and suggest improvements to reduce losses in order to improve service delivery.

The main objective of this study was to assess the level of water losses in selected areas of Harare, Zimbabwe, and to investigate opportunities for their reduction. Specifically, the study aimed at evaluating the non-revenue water situation in Harare Water and assessing the contribution of water leakage to water losses in selected areas of Harare.

**STUDY AREA**

**Location**

Harare is the capital and largest city in Zimbabwe, and is located in the north-east of the country (Figure 1). It is surrounded by the satellite towns of Chitungwiza, Norton, Epworth and Ruwa. It has an area of 890 km$^2$ and is Zimbabwe’s industrial and commercial centre.

Harare’s population has been growing rapidly for the past three decades, and in 2012 had a population estimated at 1.4 million. Between 1982 and 1992, Harare had a sudden population increase from 0.7 to 1.2 million people (Hove & Tirimboi 2011). The satellite towns of Ruwa, Epworth, Chitungwiza and Norton had a population approximating to 630,000 (ZIMSTAT 2012).

The study was carried out in Harare and focused on the four suburbs of Budiriro, Belvedere, Mabelreign, and Glen View, as shown in Figure 1.

**Water supply and sanitation services**

Water supply in Harare is managed by the Water and Sanitation Department of the City of Harare (Harare Water). Harare Water is also responsible for supplying bulk treated water to the surrounding towns of Chitungwiza, Norton, Ruwa and Epworth. Drinking water is produced from two water treatment plants owned and operated by Harare Water. The first one is the Morton Jaffray Water Works, which abstracts raw water from Lake Chivero and Lake Manyame with capacities estimated to be 247,180 and 480,240 ML, respectively (Nhapi et al. 2002). The second one is the Prince Edward Plant, which receives raw water from the Harava and Seke Dams with capacities estimated to be 9,030 and 3,380 ML, respectively (JICA 1996). Morton Jaffray has a design capacity of 614 ML/day and Prince Edward has a design capacity of 90 ML/day (Nhapi et al. 2002). Due to deteriorated infrastructure at the treatment works, the total output was restricted to 600 ML/Day (MJ 526 ML/Day and PE 74 ML/Day). In 2012, water demand was reported to be around 1,200 ML/day by the City of Harare. However, this figure needs to be verified given the current situation on the ground, including low industry performance.

The water supply network is composed of about 5,500 km of transmission and distribution mains with pipe diameters ranging from 50 mm to 1,500 mm (steel, asbestos cement, PVC). There are 15 booster pump stations and 28 concrete reservoirs with a total capacity of 850 ML. It is estimated that there are 192,000 customer connections. The sewerage collection network for Harare is aging, with
The selection of Harare as the study area was based on its reported high levels of NRW, ranging from 57 to 60% of water production, which is very high compared to the NRW of 23% recommended by the World Bank (Tynan & Kingdom 2002). Such a situation dictates urgent measures be taken to reduce losses (DHI 2012). Furthermore, the contribution made by water leakage from distribution mains was unknown in Harare. The study was carried out in the selected suburbs of Budiriro, Glen View, Belvedere and Mabelreign. These suburbs were selected based on their unique characteristics, in the sense that each suburb formed a distinct zone that did not link to other areas and was supplied by distinct feeder mains. All zones had residential or individual customers, and the bulk meters installed were compatible with the loggers that were used for flow and pressure logging. They were also among the few areas in Harare that were receiving a near-continuous water supply at the time of study.

Data collection

Data loggers (Biwater Spectrascan) were installed in the selected four suburbs of Budiriro, Glen View, Belvedere and Mabelreign for flow and pressure measurements. The Budiriro and Belvedere areas are each supplied with water...
from a single feeder, Glen View has two feeders and the Mabelreign areas is supplied by three feeders. Two field measurement campaigns were carried out, with the first one being from 20 April to 1 May 2012 and the second from 10 May to 18 May 2012. Data on customer monthly water consumption for April, number of customers, number and type of customers was collected from the billing section of Harare Water. Information on age, diameter and length of water mains, and number of service connections, was obtained from the distribution section of Harare Water. Semi-structured interviews were conducted with relevant senior Harare Water staff on issues related to causes of water loss in Harare, strategies used for management of water loss and the levels of implementation of the strategies, metering, meter reading and billing.

Data analysis

The amount of water leakage contributing to the water losses for the selected supply zone was determined from the South African Night Flow Analysis Model (SANFLOW version 2.03). The model was developed by the South African Water Research Commission in order to determine real losses in a particular supply zone using the recorded minimum night flows (MNFs) as the major input (McKenzie 1999). Water leakage was estimated as the system’s excess night flow (ENF) by subtracting the expected minimum night flow (EMNF) from the measured MNF. According to McKenzie (1999), the MNF is the lowest flow into the District Metered Area (DMA) over a 24-hour period, which generally occurs between 12 am and 4 am when most consumers are inactive. Table 1 presents the components of night flows.

Although customer demand is minimal at night, there is still a small amount of flow in the system owing to night-time customer demand for such uses as toilet flushing, washing machines, etc. This flow is termed ‘EMNF’ (Werner 2011). In urban situations, about 6% of the population will be active during the minimum night-time flow period (McKenzie 1999). Apart from the MNF data, the SANFLOW model also requires basic infrastructure variables as presented in Tables 2 and 3. Where there was no data such as leakage coefficients and pressure correction factors, some assumptions were made and SANFLOW default values that were recommended by McKenzie (1999) were used. Household size was adopted from the 2012 Census Report to be 4.2 people (ZIMSTAT 2012) in order to estimate the population served by the total number of connections.

According to Fanner (2004), the portion of night flows directly attributed to leakage can be derived from the following mathematical equations:

\[
\text{Expected minimum night flow} = \text{background losses} + \text{normal night use} \quad (1)
\]

\[
\text{Excess night flow} (\text{ENF}) = \frac{\text{measured MNF}}{\text{expected minimum night flow}} - 1 \quad (2)
\]

\[
\text{Leakage} (\text{m}^3/\text{month}) = \frac{\text{ENF} (\text{m}^3/\text{hr})}{(\text{hour/day factor}) \times 30 \text{ days/month}} \quad (3)
\]
The maximum ENF value was used, hence the hour/day factor was taken as 24 as recommended by Lambert (2002).

**RESULTS AND DISCUSSIONS**

**Evaluation of the water loss management in Harare**

Key informants from the water production, distribution and billing sections were interviewed on issues related to water production, water billing, causes of water loss and its management to gather information on water loss management in Harare Water. Other data were gathered from the utility records and reports. The following sub-sections present research findings for the water loss situation in Harare.

**Water production and NRW trends for Harare City**

Figure 2 presents water production trends and NRW trends for the period 2009–2011 in Harare. The data was obtained from the records of Harare Water.

From Figure 2, it can be seen that water production generally increased in the period 2009–2011. All urban areas received support in the form of water treatment chemicals from UNICEF following the cholera outbreak of 2008. Shortage of chemicals had been cited as a major constraint to water production at the peak of the economic crisis in

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**Table 3** Leakage parameters used in SANFLOW model as recommended by McKenzie (1999)

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background losses from mains (L/km. hr)</td>
<td>40</td>
</tr>
<tr>
<td>Background losses from connections (L/conn.hr)</td>
<td>3</td>
</tr>
<tr>
<td>Background losses from properties (L/conn.hr)</td>
<td>1</td>
</tr>
<tr>
<td>% of population active during night</td>
<td>6</td>
</tr>
<tr>
<td>Quantity of water used in a cistern (L)</td>
<td>10</td>
</tr>
<tr>
<td>Background losses pressure exponent</td>
<td>1.5</td>
</tr>
<tr>
<td>Burst/leaks pressure exponent</td>
<td>0.5</td>
</tr>
<tr>
<td>Exceptional use m³/hr</td>
<td>–</td>
</tr>
</tbody>
</table>

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**Figure 2** Trend of water production and NRW for Harare for the period 2009–2011.
Zimbabwe in 2008. The trend of NRW shows that it was decreasing from 2010. This could have been due to some major pipe replacements that were carried out in the CBD and other problematic areas after government released about USD 17 million for works on water and sewerage repair and rehabilitation works for Harare. During the same period, there were awareness campaigns by Harare Water on water leakage. However, the NRW increased again in 2011. In 2011, the city had stopped replacing old pipes and the awareness campaigns. The daily water production in 2012 was 600,000 m$^3$/day, giving a monthly average of 18,000,000 m$^3$. Key informants interviewed during the study estimated the daily water demand in 2012 to be approximately 1,200,000 m$^3$/day.

NRW for the entire city was established to be in the range of 43–74% between 2009 and 2011 and averaging 59. This NRW level is higher than the benchmark value of less than 23% recommended by the World Bank (Tynan & Kingdom 2002). A similar study was carried out in Zomba City (Malawi) by Chipwaila (2009), where she found that the amount of NRW was averaging 36.2%, which was also concluded to be higher than the level recommended for well-performing water utilities in Southern Africa.

In this study (Harare), the areas where water is being lost were reported to be along the transmission mains, distribution mains and service connections. The main factors that could be contributing to the high water losses in Harare include high frequencies of pipe bursts driven by the age of the infrastructure, tree roots and sometimes damage by contractors. A significant portion of the water and sewerage reticulation was laid in the period 1960–1980. Major works on water and sewerage infrastructure were last carried out in the early 1990s under World Bank funding, although most were on treatment works and main lines. In Harare, the average number of bursts per month during the study period was 545, translating to more than 0.03 bursts/conn.year (1.19 bursts/km.yr) based on the known number of connections. The figure of 1.19 pipe bursts per km every year was benchmarked with 0.2 pipe bursts per km per year maintained by Anglian Water in the United Kingdom (Anglian Water 2012). The rate of pipe bursts is higher, and this implies that the system may be dilapidated and requires replacement. The other reasons for high losses stated by key informants were failure of pressure reducing valves, vandalism and water thefts, and unregistered customers.

Metering, meter reading and water billing

The City of Harare uses a combined billing system, meaning that the bill includes rates, refuse, water, sewerage and other applicable charges. Combined billing may affect revenue collection for water if the quality of other services included in the bill is perceived as poor by customers. Revenue collection was reported to be low during the study period, and barely exceeded 60%. Based on meter reading results, the faulty metering rate for the year 2006 was 25% for the whole Harare Water supply area, while in 2011 the faulty metering rate was reported to be 35% (City of Harare 2011). From the records obtained from Harare Water, it was noted that the faulty metering rate for Budiriro was 18%, Glen View (21%), Belvedere (27%) and Mabelreign (30%). The monthly consumption for customers with stuck meters is based on estimates from previous consumption (the average monthly consumption for one year when the meter was working). Recommended domestic meter replacement time is seven years (Zane & Bhardwaj 2004). Taking a case study from Kampala, Uganda, it was noted that meter inaccuracies contributed to 22% of NRW due to under registering consumptions (Mutikanga et al. 2010). It therefore appears that the faulty metering rate of 35% city wide is very high, and the method of monthly consumption estimation can affect both customers and utilities, especially given the erratic water supply.

Water loss management strategies for Harare Water

Key informants reported that Harare Water implements different strategies to reduce water losses in order to improve service delivery and revenue collection. Strategies being implemented by Harare Water target four areas: (1) system leakages on trunk and distribution mains; (2) poor revenue collection (metering and illegal consumption); (3) poor customer focus; and (4) poor and inadequate system maintenance. For system leakage reduction, Harare Water is implementing pipe replacement, servicing of pressure control valves, leak and burst pipe repairs, and surveillance of trunk and distribution mains in different areas of Harare.
However, this is affected by financial constraints. To address the poor revenue collection, in the year 2012 Harare Water bought 40,000 customers meters and was replacing 12,000 non-functional meters in Mabvuku/Tafara and another 28,000 meters in different areas of Harare. To improve revenue collection, Harare Water normally disconnects the service for the non-paying customers to enforce payment of outstanding bills. To address poor customer focus, a 24-hour call centre was established by Harare Water in 2010. For inadequate system maintenance, increased lobbying for funds from central government and increased allocation of revenue towards repairs are the two strategies used. Other strategies that Harare was proposing included setting up a Task Force for active leakage detection, an awareness campaign program, implementation of prepaid water meters, implementation of cell phone meter reading and surveillance for water theft and illegal connections. The Self Assessment Matrix on NRW management for best practice developed by the African Development Bank (AfDB 2011) was adopted by Harare Water to assess levels of interventions for each NRW management strategy. Using this matrix and information obtained from Harare Water, the overall NRW management was 2.7 out of 5, which can also be presented as 53.4% implementation of NRW strategies. Overall, the implementation of NRW management strategies by Harare Water is just intermediate to minimize losses to the acceptable values.

Given the high NRW, possible financial and economic approaches to rectifying the high NRW in Harare include updating the customer database, meter installation (for those unmetered) and replacement, and piloting prepaid meters. It is estimated (by Harare key staff) that some 50,000 customers are not in the database of Harare. The average water bill is about USD 15 per month per each domestic connection. Thus updating the customer database could result in an increase of USD 750,000 monthly. This revenue should be able to finance meter installation and replacement, given that the average cost of a new domestic meter is around USD 75–100. After meter installation and replacement, revenue will easily increase by over USD 1 million monthly. However, complementary strategies to ensure improvement in bill collection efficiency will be needed. The city has been planning to install prepaid meters. Thus an increase in revenue from improved metering and billing will create the funding needed to procure and install prepaid water meters. The overall improvement in revenue from improved metering and billing will enhance the financial capacity needed to finance or repay loans for pipe replacement, which requires substantial capital.

**Water consumption trends for Budiriro and Glen View suburbs**

Water consumption data for 2006–2011 for Budiriro and Glen View suburbs was collected from the billing records maintained by the City of Harare. The consumption data for the other two suburbs of Belvedere and Mabelreign were not fully available for the period of 2006–2011. The water consumption trend for Budiriro suburb is presented in Figure 3 for the period of 2006–2011, while the water consumption trend for Glen View suburb is presented in Figure 4 for the period of 2006–2011.

From Figure 3 it can be seen that there was no increase in consumption in Budiriro Suburb. The population
increased at an average annual growth rate of 1.1% in Harare during the period of 2006–2011 (ZIMSTAT 2012). This could explain why there was no substantial increase in consumption. Figure 4 shows the consumption trends in Glen View Suburb with a decreasing trend from 2006 to 2011. Again this can be attributed to the deterioration of infrastructure. Harare Water should have the plan for water mains renewal to reduce losses. In 2008, the production went down (Figure 5). This was due to many factors including the collapse of infrastructure and failure by local authorities to procure chemicals (PWC 2012). The situation was worsened by the country's economic crisis, which reached a critical level during that period (2007–2009) (City of Harare 2011). The water production data was collected from records of water production maintained at the water works by the City of Harare.

**Contribution of water leakage to the water losses in selected areas**

**Assessment of water flow pattern in selected areas**

The results of water flow measurements carried out in April–May 2012 in the selected four suburbs are presented graphically in Figures 6–12.

From Figure 6 it can be seen that the MNF, which according to Thornton (2005) usually occurs during the night between 12 and 04 am, was ranging from 193 to

![Figure 4](image1.png)  
**Figure 4** | Glen View suburb water consumption trends for the period of 2006–2011.

![Figure 5](image2.png)  
**Figure 5** | Harare Water average daily water production from January 2006 to December 2011.
199 m³/hr during the entire logging period. The average flow was 586 m³/hr during the logging period.

Figure 7 shows the results of the inflow pattern to the Belvedere water supply area. The MNF was ranging from 74 to 83 m³/hr during the entire logging period. The average flow was calculated to be 181.1 m³/hr during the logging period. There were 2 days where the area had a period of water cuts that were possibly due to either a major pipe burst or power cuts that the City of Harare was experiencing during the period of study.

Figure 8 presents the MNF from Feeder 1 ranging from 104.7 to 113.3 m³/hr during the entire logging period with the average flow calculated to be 203.0 m³/hr. Figure 10 presents the flow to Glen View area from Feeder 2, and the MNF was ranging from 100.7 to 106.4 m³/hr during the entire logging period with the average flow calculated to be 196.0 m³/hr. There were days where the area had periods of no flows due to rationing by closing valves to allow water to flow to other areas. Rationing of flow was also adopted by the City of Harare to ensure a fair distribution of water to its
customers given the high water demand compared to production capacity.

Figures 10–12 present the results of the inflow pattern for the three feeders to the Mabelreign water supply area from 20 April to 1 May 2012. Figure 10 shows that the MNF from Epsilon Reservoir to Mabelreign varied from 56.1 to 59.2 m³/hr with an average flow into the area of 95.3 m³/hr. Figure 11 presents the flow pattern into Mabelreign from Feeder 2. The flow MNF was from 40.0 to 44.4 m³/hr and average inflow was 66.9 m³/hr. There were periods in 3 days when the logger did not record any flows. The no flow situation could have been due to water rationing. Figure 12 shows that the MNF

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**Figure 8** | Glen View area water supply inflow pattern from Feeder 1 for the period of 20 April to 1 May 2012.

**Figure 9** | Glen View area water supply inflow pattern from Feeder 2 for the period of 20 April to 1 May 2012.
to Mabelreign area from Feeder 3 was ranging from 36.4 to 41.3 m³/hr during the entire logging period. The average flow was calculated to be 72.2 m³/hr. There were also periods in 3 days when the logger on Feeder 3 did not record any flows, possibly due to water rationing.

Based on the results of the flow patterns from the four selected suburbs, it was established that the water flow pattern in all of the study area is not continuous and this makes it less reliable to consumers, contrary to the best practice of 24 hour water flows to customers as stated by WHO (2000). The discontinuous water supply has an implication of not satisfying the consumers, which might affect their willingness to pay for the service.

**Estimated leakage in the four selected areas**

Leakage in the selected study areas was assessed using flow data recorded by the loggers and the records obtained from
the billing section. Table 4 presents the estimated leakage from the study areas.

ENF was calculated from Equation (2) as recommended by McKenzie (1999). The number of connections and length of pipeline used in the computations are from Table 2.

From Table 4, leakage in Budiriro was approximately 26.7% of water supplied to the area. Belvedere had 35.3% as leakage, Glen View 31.2% and Mabelreign 36.5%. The age of the pipelines in the areas was also assessed. Since construction, there had been no major pipe replacement carried out in these areas, rather than replacing pipes when bursts occurred. Thus, most pipe materials in Budiriro are 20 years old, in Belvedere 40 years old, in Glen View 34 years old and in Mabelreign 47 years old. The pipe materials are mainly asbestos cement (AC) in these areas.

Environmental factors and installation practices affect the actual life that can be achieved (Folkman 2012).

Contribution of water leakage to water losses in the four selected areas

The contribution of water leakage to the water losses was evaluated as a proportion of measured water leakage to the calculated water loss expressed as the percentage of water supplied, as shown in Table 5.

From Table 5, Budiriro water consumption for April 2012 of 268,769 m³ represented 63.7% of what was supplied (421,992 m³). Belvedere was 71.3%, Glen View was 63.4% and Mabelreign was 57.1%. This information gives an equivalent total water loss of 36.3% for Budiriro, 28.7% for

<table>
<thead>
<tr>
<th>Water supply area and year of construction</th>
<th>Average ENF (Equation (2)) (m³/hr)</th>
<th>Average monthly leakage (Equation (3)) (m³)</th>
<th>Average zone daily flow (m³/hr)</th>
<th>Equivalent monthly supply (m³)</th>
<th>Estimated water leakage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% of supply</td>
<td>m³/conn/ mth</td>
<td>m³/km/ mth</td>
<td>Budiriro (1989–1992)</td>
<td>156.2</td>
</tr>
<tr>
<td>Belvedere (1972)</td>
<td>63.5</td>
<td>35.3</td>
<td>46.7</td>
<td>46,008</td>
<td>181.1</td>
</tr>
<tr>
<td>Glen View (1978)</td>
<td>124.4</td>
<td>89,568</td>
<td>399.1</td>
<td>287,352</td>
<td>31.2</td>
</tr>
<tr>
<td>Mabelreign (1965)</td>
<td>85.6</td>
<td>61,632</td>
<td>234.3</td>
<td>168,696</td>
<td>36.5</td>
</tr>
</tbody>
</table>
Belvedere, 36.6% for Glen View and 42.9% for Mabelreign. The water consumed was based on billing records for the City of Harare for the same period.

From the estimate of quantified leakage presented in Table 4, it is obvious that the value of water leakage is lower than the value of water loss, and the rationale of water loss is the combination of apparent and physical water losses. The three study areas of Budiriro, Glen View and Mabelreign gave positive results. Belvedere gave a negative result by showing the measured water leakage to be higher than the water loss calculated from meter readings of the bulk meter and customer meters. This might have been attributed to the faulty metering rate (27% was obtained from the records), and perhaps the bulk meter may have been faulty.

Harare Water key informants reported that Belvedere is amongst the areas with a high rate of customers with stuck meters; monthly consumption for customers with stuck meters is obtained by estimation. The presence of stuck meters was also reported during the household survey. Key informants reported that it is difficult to access a significant portion of the properties in this area for reasons including some consumers in these areas refusing to cooperate with the meter readers by refusing to give them access. Some of the meters were reported to be very old (more than 15 years of age) and, according to the best practices for the reduction of unaccounted for water developed by the World Bank, meter replacement should be done after every 10–15 years to keep them accurate (Yepes 1995). According to Yepes (1995), water utilities in Singapore (World Best Performance) domestic water meters are replaced after every seven years and large meters after every four years. Because of financial constraints, Harare Water has not managed to replace water meters on time.

With these challenges, it is likely that the monthly consumption figures may be unreliable.

A study by Seago et al. (2004) for benchmarking water leakage from a reticulation system using data from 27 water supply systems in 19 countries came up with a water leakage benchmark value of 276 L/connection/day. From Table 6, the amount of water leakage quantified in the Harare Water study areas ranged from 269.0 to 807.2 L/connection/day. The average for the four areas was 512 L/connection/day. From these figures, it can be concluded that water leakage in Harare Water is above the international benchmark suggested by Seago et al. (2004). Seago et al. (2004) also carried out a study in 30 South African water supply systems and reported an average leakage value of 340 L/connection/day.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Water loss in the specific study areas was high (29–43%) and exceeded the 23% benchmark suggested by the World Bank. The contribution of water leakage to the water loss was found to be high in the selected study areas, and contributed

<table>
<thead>
<tr>
<th>Water supply area</th>
<th>Water supplied (m³) per month</th>
<th>Water consumed (m³) per month</th>
<th>Water loss (m³) per month</th>
<th>Water leakage (m³) per month</th>
<th>Water leakage (%)</th>
<th>Contribution of water leakage to the water loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budiriro</td>
<td>421,992</td>
<td>268,769.0</td>
<td>153,223.0</td>
<td>112,464</td>
<td>36.3</td>
<td>26.7</td>
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<tr>
<td>Belvedere</td>
<td>130,392</td>
<td>92,986.8</td>
<td>37,405.2</td>
<td>46,008</td>
<td>28.7</td>
<td>35.3</td>
</tr>
<tr>
<td>Glen View</td>
<td>287,352</td>
<td>182,036.0</td>
<td>105,316.0</td>
<td>89,568</td>
<td>36.6</td>
<td>31.2</td>
</tr>
<tr>
<td>Mabelreign</td>
<td>168,696</td>
<td>96,289.8</td>
<td>72,406.2</td>
<td>61,632</td>
<td>42.9</td>
<td>36.5</td>
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<table>
<thead>
<tr>
<th>Water supply area</th>
<th>Number of connections</th>
<th>Water leakage m³/month</th>
<th>L/conn/day</th>
</tr>
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<td>Budiriro</td>
<td>11,400</td>
<td>112,464</td>
<td>328.8</td>
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<td>807.2</td>
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<tr>
<td>Glen View</td>
<td>11,100</td>
<td>89,568</td>
<td>269.0</td>
</tr>
<tr>
<td>Mabelreign</td>
<td>3,200</td>
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<td>642</td>
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</tbody>
</table>
to the larger portion of total losses in all areas (over 70%). The major driver for leakage was the age of the systems in the study areas, which in some areas was over 40 years. The high faulty metering rate may have affected some of the results in the study. Furthermore, it was concluded that the level of implementation of water loss management strategies was low. NRW for Harare ranged from 43 to 74% between 2009 and 2011, and this could be affecting the quality of service delivery.

Recommendations

It is recommended that the city embarks on a programme to update the database and meter unmetered customers in the short term. An increase in revenue from an updated customer database will enable gradual replacement of all faulty meters in the medium term thereafter; pipe replacement, starting with hot spots for leakage, should be carried out in the medium to long-term. The City of Harare should set up a Task Force to oversee water loss reduction, develop a water loss strategy and set up a unit for water loss reduction. Regular water audits following the IWA Water Balance Model should be carried out by Harare Water.

ACKNOWLEDGEMENT

This paper presents part of the research results of an MSc study by Michael Gregory Ndunguru at the University of Zimbabwe under a WaterNet Fellowship.

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First received 24 September 2015; accepted in revised form 20 August 2016. Available online 28 September 2016.