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THE CONTRIBUTION OF LEAKAGE WATER TO TOTAL WATER LOSS IN HARARE, ZIMBABWE

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ABSTRACT

Many water loss management studies assess Non Revenue Water (NRW) without evaluating the contribution of leakages to total water losses. The objective of this study was to evaluate the contribution of water leakages to the total water loss of the City of Harare, Zimbabwe. NRW was partitioned and leakages were evaluated using SANFLOW (South African Night Flow) Analysis model in four district metered areas of Harare. The study concluded that 36 % of the total water supply was being lost monthly. Of the 36 % water lost, 33% is lost as leakage water every month. With the Greater Harare area having nearly 200,000 connections, each connection loses an average of $5.50 every month. Thus, the City of Harare is losing over one million dollars monthly. Therefore, the City of Harare should be proactive in reducing leakages since leakage losses negatively affect service delivery.

Key words: Non Revenue Water, Water Leakage, SANFLOW

1. INTRODUCTION

The main objective of water utilities is to supply the right quantity and quality of water at the right time to the satisfaction of their consumers. However, in their attempts to achieve this objective, water utilities are confronted with a series of challenges. Their main challenge in water distribution is in dealing with leakages. This problem is exacerbated by poor and aged infrastructures. The major obstacles faced by utilities in infrastructure replacement are: (i) understanding when replacement will be required, (ii) how to schedule it over several decades, and (iii) how to pay for it in a fiscally prudent manner (AwwaRF, 2007, Zalewski, 2002). Although water mains deterioration is inevitable, it is necessary to quantify infrastructure deterioration rate in order to implement effective renewal plans for water distribution networks (Kleiner and Rajani, 2002). Water utilities require short-term planning for operational purposes and long-term planning for capital expenditure plans (Olsen, 2005).

Leakages seem inevitable, thus making it difficult to provide the right quantity and quality of clean drinking water on a timely basis (Kleppen, 2011). Kingdom *et al.* (2006) reported that, water losses in developing countries average approximately 50%, with the greatest fraction emanating from leakages. Mutikanga *et al.*, (2009) reported levels of water losses of about 40% for the National Water and Sewerage Corporation (NWSC) of Kampala (Uganda). The major causes of water losses in Harare are: (i) old pipe networks dating back to the 1960s (ii) lack of knowledge of the water distribution networks (inadequate records), and (iii) low awareness on partitions of NRW, (City of Harare, 2011). The problem of water losses in general and leakages in particular in developing countries is due to poor strategic management, weak financial and operational management, unskilled staff, low funding priority to the water sector, weak customer service orientation, political interference and little or no independent regulation or oversight (Water Operators Partnerships, 2009). Furthermore, there are no set methodologies or tools that can be used to analyze, reduce and control different components of water losses in the distribution system in developing countries (Farley, 2003). However, several methods exist for detecting water distribution system leaks (Lahlou, 2011). These methods usually involve using sonic leak-detection equipment, which identifies the sound of water escaping a pipe (Govt of India and WHO, 2005). These devices can include pinpoint listening devices that make contact with valves and hydrants, and geophones that listen directly on the ground. In addition, correlator devices can listen at two points simultaneously to pin-point the exact location of a leak (EPD, 2007). Unfortunately, not all water utilities are privy to these methodologies for various reasons. Some of the reasons include lack of political will, lack of financial and human resources, and institutional resistance to change and adopt new innovations.

The Training Manual for the best practice for the leakage management and control by Farley (2001) argues that there are a range of factors that are responsible for water leakage. The most common ones are pressure, type of piping materials and their age, soil condition and movement, poor quality of materials and workmanship. Although sufficient pressure is needed to convey water through the pipe network, pressure can cause water loss in several ways such as increasing leakage due to increased pressure, increasing burst frequency as a consequence of increased pressure or pressure surges (water-hammer effect); pressure cycling as a result of frequently on/off switching of pumps or faulty pressure-reducing valves can cause plastic pipes to burst (Lambert, 2002). As a result pressure management is one of the most important Water Demand Management (WDM) interventions that can be implemented by water utilities in reducing Non Revenue Water originating from water leakages (Lambert, 2002). Since leakage is pressure driven, all efforts resulting in the reduction of water pressure will reduce the water leakage to some extent. For example, doubling pressure will result in approximately 41% increase in leakage (WRC, 2001). Although systems are designed to accommodate minimum levels of pressure and flow required during peak demand which would normally occur at some specific time of the day and during a particular month in the year, pressure regulation becomes the most vital operational procedure. In other words, the systems are designed to provide the appropriate supply during a very short period of the year and for the remainder of the time the systems tend to operate at pressures significantly higher than required (McKenzie and Wegelin, 2009). Water pressure during the off-peak periods; tend to be much greater than the peak periods (McKenzie and Wegelin, 2009).

Reducing water pressure in a water distribution system can be achieved through the use of fixed outlet pressure control devices (e.g. Pressure Reducing Valve), time-modulated pressure control devices and flow modulated pressure control devices. During the off-peak periods, the time-modulated pressure can provide a further reduction in pressure. This form of pressure control is useful in areas where water pressures build up during the off-peak periods, typically during the night when most of the consumers are asleep (McKenzie and Wegelin, 2009). Flow modulated pressure control devices provide greater control, flexibility and greater savings. Flow modulated option will not obstruct the water supply in the case of fire. Assessment of pressure and flows within a water supply area can be done by employing the data loggers designed to record the pressure and flows (McKenzie, 1999). After assessment of water flow and pressure in a metered area and once the performance is found to be out of normal operating parameters suspicion is raised, hence need for leakage detection (EPD, 2007). However, Night Flow Analysis Modelling (McKenzie, 1999) is the best practice analysis and monitoring strategy for the water leakage within a District Metered Area (DMA), (Hunaidi, 2010). This analysis is done when the customer demand is at its minimum and therefore the leakage component is at its largest percentage of the flow.

The objective of this paper is to evaluate the contribution of water leakages to non revenue water in Harare, Zimbabwe. This was done using South African Night Flow (SANFLOW) analysis model. A computation of the leakage water as a fraction of the total water loss was then done followed by costing of the leakage in selected DMAs in Harare.

2. STUDY AREA

The study was undertaken in Harare, Zimbabwe. The Greater Harare region has a population of about 2.1 million people (Zimbabwe National Statistical Agency, 2012). The water supply to Greater Harare is operated by Harare Water, a water arm of the Municipality of Harare. Harare Water supplies water to almost 200,000 connections within the Greater Harare region. Fig.1 shows the location of Harare and the selected four district metered areas (DMAs) used in this study. The choice of these areas was based on reliability of water supply to these DMAs.

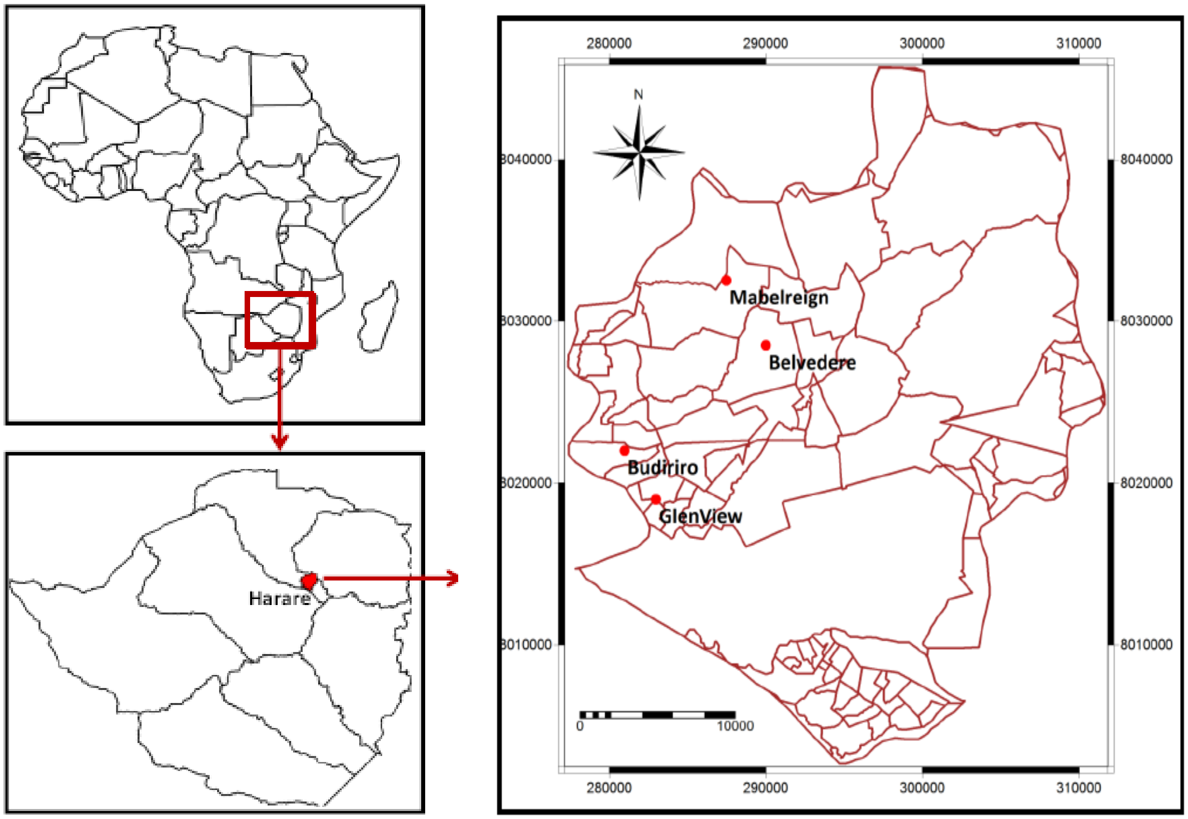

Fig.1: *Map of Harare showing selected DMAs*

3. MATERIALS AND METHODS

3.1 DATA PRESENTATION AND ANALYSIS

Descriptive statistics and graphical representation of data was used to analyze data collected from the City of Harare. This is counting the frequency or the number of times that certain things happen and presenting the information in a table or graphical way which is easily understood by most people.

3.2 QUANTIFICATION OF WATER LEAKAGE AND ITS CONTRIBUTION TO WATER LOSSES

The amount of water leakage contributing to the total water loss for the selected water supply zones was analysed using the South African Night Flow (SANFLOW) Analysis Model version 2.03. The model was developed by the South African Water Research Commission in order to help water suppliers to determine the level of unexplained burst leakage in a particular supply zone from the analysis of recorded minimum night flows (McKenzie, 1999). Basically the estimation of water leakage was calculated as the system's Excess Night Flow (ENF), which was determined by subtracting the Expected Minimum Night Flow (EMNF) from Minimum Night Flow (MNF). The MNF is the lowest flow into the DMA over a 24-hour period, which generally occurs between 00:00hours and 04:00hours when most consumers are inactive. This MNF can be measured directly from the data logging device or the flow graph. Table 1 presents the components of night flows used in this study.

Table 1. Components of the night flow.

Components of night Flow	Composition	Abbreviation	Unit	Component value
Expected Minimum Night Flow (EMNF)	Domestic users	Q_{dom}	[L/h]	Estimated
	Small Non-Domestic users	$Q_{bulk,small}$	[L/h]	Estimated
	Large Non-Domestic users	$Q_{bulk, large}$	[L/h]	Measured
Transfer	Transfer of water to neighbouring zones	Q_{trans}	[L/h]	Measured
Excess Night Flow (ENF)	Background losses	$Q_{loss,BG}$	[L/h]	Estimated
	Burst pipes	$Q_{loss,B}$	[L/h]	Calculated

(Source: McKenzie, 1999)

Although customer demand is minimal at night, researchers still have to account for the small amount of Expected Minimum Night Flow (EMNF), i.e. the night-time customer demand, such as toilet flushing, washing machines, etc. Typically, 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 uses basic infrastructure variables such as length of mains, number of connections; number of properties, estimated population, average zone night pressure and major water users. Where there was no data such as leakage coefficients and pressure correction factors, some assumptions were made and SANFLOW default values which were recommended by McKenzie (1999) were used. Tables 2 and 3 provide the base information and assumed parameters which were used in the SANFLOW model for each of the study area.

Table 2: Infrastructure variables used in SANFLOW Model

Description	Value			
	Budiriro	Glen View	Belvedere	Mabelreign
Length of mains (km)	90.17	109.86	98.45	93.97
Number of connections	11421	11100	1899	3241
Number of properties	11421	11100	1899	3241
Estimated population	57105	55500	9495	16205

Table 3: Leakage Parameters Used in SANFLOW Model

Description	Value				
	Default	Budiriro	Glen View	Belvedere	Mabelreign
Background losses from mains (l/km.hr)	40	40	40	40	40
Background losses from connections (l/conn.hr)	3	3	3	3	3
Background losses from properties (l/conn.hr)	1	1	1	1	1
% of population active during night	6	6	6	6	6
Quantity of water used in a cistern (l)	10	10	10	10	10
Background losses pressure exponent	1.5	1.5	1.5	1.5	1.5
Burst/leaks pressure exponent	0.5	0.5	0.5	0.5	0.5
Exceptional use m^3/h	-	-	-	-	-

Expected Minimum Night Flow = Background losses + Normal night use……Equation 1

ENF = Measured MNF – Expected Minimum Night Flow..................................Equation 2

Leakage (m^3/month) =ENF (m^3/hr) × (hour/day factor) × 30 days/month………Equation 3

4. RESULTS AND DISCUSSIONS

4.1 WATER PRODUCTION AND NRW TRENDS

Fig. 2 presents water production and NRW trends for the period of 2009 to 2011 in Harare. The trend shows that on average 14 million cubic meters of water was produced each month. An average of 40% NRW was recorded in the period January 2009 to December 2011.

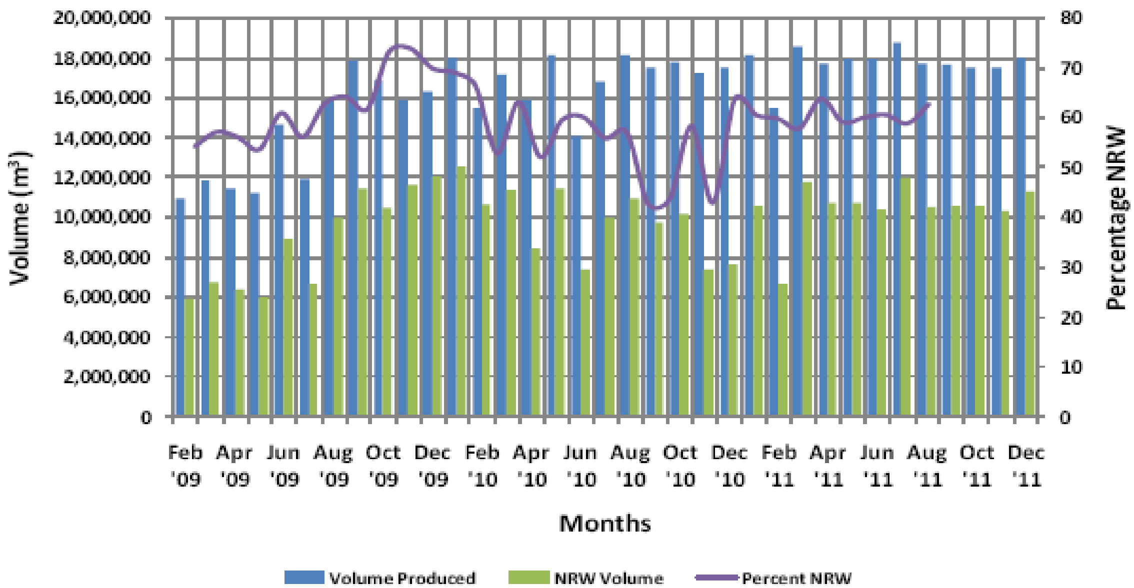

Fig. 2 *Water supply and NRW for period 2009-2011*

Table 4: Estimated water loss in the four selected study areas

Water Supply Area	Monthly Average		% Consumption	% Loss
	WATER SUPPLY (m^3)	WATER CONSUMPTION (m^3)		
Budiriro	421959	268,769	64	36
Belvedere	130419	92,987	71	29
Glen- view	287333	182,036	63	37
Mabelreign	167111	96,290	58	42
Average			64	36

Table 5: Estimated leakage in the four selected study areas

Water supply area	Average excess night flow M^3/hr	Average monthly Leakage M^3	Average zone Daily flow M^3/hr	Equivalent monthly supply M^3	Estimated water leakage		
					% supply	m^3/conn./ month	l/conn./d
Budiriro	156	112474	586	421959	27	9.85	328
Belvedere	64	46015	181	130419	35	24.23	808
Glen-View	62	89537	200	287333	31	8.07	269
Mabelreign	29	61743	77	167111	37	19.05	635
Average					33	15.30	510

Data on monthly water consumptions for the study areas were collected from Harare Water to establish the proportion of water supplied and water consumed. From Table 4, Budiriro suburb water consumption for April 2012 was 64% of the total supplied. Belvedere was 71%, Glen View was 63% and Mabelreign was 58%. This information gives equivalent water loss of 36% for Budiriro, 29% for Belvedere, 37% for Glen View and 42% for Mabelreign. For Budiriro, out of 36% total water loss, water leakage was 27%, for Glen View out of 37% total water loss, water leakage was 31% and for Mabelreign area out of 42% total water loss the amount of water leakage was 37%. A similar study was done in Kampala, Uganda by Mons (2010) where it was found that the contribution of water leakage to the water loss was 29%. Based on the study by Seago *et al.* (2004) which benchmarked water leakage to 276 litres/connection/day, the amount of leakage ranged from 269 litres/connection/day to 808 litres/connection/day (average of 510 litres/connection/day), which was above the international benchmark derived from 27 water supply systems data in 19 countries. Also, Seago *et al.* (2004) reported an average leakage value of 340 litres/connection/day based on 30 South African water supply systems.

This study further endeavoured to estimate the average cost of water leakage in the selected four DMAs. Table 6 shows the computation of the estimated cost of leakage water.

Table 6: Estimated cost of leakage water

WATER SUPPLY AREA	% Leakage fraction of total loss (Monthly Average)	Volume lost per connection per month (m^3/conn./month)	Water tariff (USD/m^3)	Estimated cost of leakage water (USD/conn./month)
BUDIRIRO	27	9.85	0.25	2.46
BELVEDERE	35	24.23	0.40	9.69
GLEN VIEW	31	8.07	0.25	2.02
MABELREIGN	37	19.05	0.40	7.62

From Table 6, the high-density suburbs of Budiriro and Glen-View have a tariff of USD 0.25/m^3 while the low density suburbs (Belvedere and Mabelreign) have a tariff of USD 0.40/m^3 within normal consumption tariff band. With the Greater Harare area having almost 200,000 connections and each connection loses an average of $5.50 every month, it means that the City of Harare is losing over one million dollars very month. Thus, the city of Harare should be more proactive and actively invest in leakage reduction initiatives in order to save and reinvest so as to improve water supply service delivery. By reducing total leakage water, the city would be able to postpone capital investment on new water supply and distribution system. Thus, for the case of Harare, high water losses for Belvedere and Mabelreign are due to aged infrastructure in excess of 40 years.

5. CONCLUSIONS AND RECOMMENDATIONS

The Non-Revenue Water management practice in general and water leakage practice in particular for Harare are poor as evidenced by an average water loss of 36% and an average water leakage of 33%. The four selected DMAs are the ones performing well in Harare because the NRW for the entire Greater Harare region is in excess of 40% (City of Harare, 2011). This is on the higher side compared to 23% which was recommended by the World Bank and 20% which was set for well performing urban water utilities in Southern African Region (Gumbo, 2004). The level of implementation of NRW management strategies (53%) (Ndunguru, 2012) is just intermediate and the City of Harare will not minimize these losses to the acceptable value unless increased intervention is initiated urgently. Water leakage from the distribution mains contributes greater than 70% of the total water losses in the specific study area (Ndunguru, 2012). Thus, there is need for Harare to take a more proactive approach to NRW including periodic water audits, procurement of leak detection equipment and sustained meter testing and replacement. Harare Water supply is erratic and inadequate to meet customers demand; this leaves the majority of customers with poor water service. City of Harare should increase lobbying of funds to assist in employing all NRW management practices for the ultimate improvement of water service delivery. Through this they can plan for the main replacement programme, meter programme and buy leakage detection equipment. City of Harare should periodically conduct community awareness campaigns to give consumers practical tips on how to conserve water and should also form a Task Force for leak detection.

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Statement:

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