



**BUSITEMA  
UNIVERSITY**  
*Pursuing Excellence*

**FACULTY OF ENGINEERING**

**DEPARTMENT OF MINING & WATER RESOURCES  
ENGINEERING**

**A FINAL YEAR PROJECT REPORT**

**AN AUTOMATED WATER METERING, BILLING AND  
MONITORING SYSTEM**

**NAME:** MASERUKA S. BENDICTO  
**REG:** BU/UG/2012/163  
**Tel:** 0785700880 / 0701269260  
**Email:** masbendict@gmail.com,masbendicto@yahoo.com



**PROJECT SUPERVISORS**

**MAIN PROJECT SUPERVISOR:** Mr. DAVID KIMERA

**CO PROJECT SUPERVISOR:** Mr. JOSEPH DUMBA LWANYAGA

*A final year project report submitted to the Department of water resources and mining engineering in partial fulfilment for the award of the Bachelor of Science in Water Resources Engineering degree of Busitema University*

**MAY 2016**

## **EXECUTIVE SUMMARY**

Water supply is one of the booming businesses in the world today since it involves supplying of water which is an essential and basic need to the general public. This business is carried out by water utility operators who are vested with task of extracting this resource from a raw water source, treating it and supplying it to the customers.

Most water distribution companies do not sustainably manage this resource due to low technological advancement and thus follow the conventional water meter reading and billing that follows a manual process where agents of the utility physically visit the premises of the users and manually record the consumption data for bill development and delivery for payment. This is inefficient since human errors and estimation of customers' consumption information can be made during meter reading and also a lot of time and money is invested by the company during this process. The process also being manual, it has aided theft of water by bypassing the meter. In the case of leakages, water lost in due process goes unnoticed.

**An Automated Water Metering, Billing, and Monitoring System** that automatically takes meter readings at customers' homes and transmits them to the water office where the billings are prepared eradicates this problem. With this, the customers are given due notification of their water consumption bills through text messages having their corresponding amount to be paid. Payments are issued as usual through the bank, mobile money services, etc. and in case the bill is not paid within the grace period, the system automatically disconnects the customer. Once the bill is paid including the connection charges, the reconnection is done automatically. In case of monitoring, the system detects leakages and illegal connections in dead end water networks and then notifies the operators in office of where the problems are.

This system eradicates estimated meter readings, errors made by mechanical meters due to wrong calibration or being faulty and human errors during taking of the customers' readings. It fastens the process of metering and billing, enables quick notification of leakage points to the service provider and enables an overall better management of the service by the service provider.

## Acknowledgements

I would love to thank my supervisors who guided me in writing this project report.

I thank my friends for the time and guidance they have offered towards this project

I am heavily indebted to my beloved mother, Ms. Mariam Nkutu and my family for the financial support, guidance and encouragement towards my education and upbringing.

Am very grateful for the hand offered by Mr. Kazaala Joackim and Mr. Wakoko Enos towards the implementation of this project. May God bless them dearly.

Above all, I would love to thank the Almighty God for giving me wisdom, knowledge, health and patience to learn.

## Declaration

I MASERUKA S. BENDICTO, declare that all the material portrayed in this project report is original and has never been submitted in for award of any Degree, certificate, or diploma to any university or institution.

Signature

.....  
Maseruka S. Benedicto

Date

.....  
25<sup>th</sup> - May - 2016



## Approval

This is to certify that the project has been carried out under my supervision and this report is ready for submission to the Board of examiners and senate of Busitema University with my approval.

**MAIN SUPERVISOR:** Mr. DAVID KIMERA

**SIGNATURE:** .....

**DATE:** .....

**CO-SUPERVISOR:** Mr. JOSEPH DUMBA LWANYAGA

**SIGNATURE:** .....

**DATE:** .....

## Table of Contents

EXECUTIVE SUMMARY .....	i
Acknowledgements.....	ii
Declaration.....	iii
Approval .....	iv
List of Acronyms/Abbreviations.....	ix
List of Figures.....	x
List of Tables.....	xi
List of Symbols.....	xii
CHAPTER ONE: INTRODUCTION.....	1
1.0 Background of the study.....	1
1.1 Problem statement.....	3
1.2 Significance of study.....	3
1.3 Main objective.....	3
1.4 Specific Objectives.....	3
1.5 Justification.....	4
1.6 Scope of the Project.....	4
CHAPTER TWO: LITERATURE REVIEW.....	5
2.0 Introduction.....	5
2.1.1 Assessment of water consumed.....	5
2.1.2 Water losses.....	5
2.2 Metering and Billing.....	6
2.2.1 Existing managerial metering and billing systems.....	7
2.2.2 Existing Remote metering systems.....	7
2.2.3 Existing computerized metering and billing systems.....	9
2.2.4 Existing payment systems.....	10

2.2.5	Existing water Disconnection systems.....	11
2.3	Desk/Water balance Leakage detection and monitoring methods .....	12
2.3.1	Water audit.....	12
2.3.2	Zero consumption measurement.....	12
2.3.3	Hydrostatic testing.....	13
2.3.4	Continuous flow measurement (minimum night flow).....	13
2.3.5	Passive observation.....	13
2.4	Physical leakage detection and monitoring methods .....	13
2.4.1	Acoustic detection methods.....	13
2.4.2	Transient flow methods.....	14
2.5	Theft prevention systems .....	15
2.6	State of the current NWSC systems .....	16
2.7	Project components .....	17
2.7.1	Flow meter .....	17
2.7.2	Water Solenoid Valve.....	18
2.7.3	Micro water turbine generator .....	18
2.7.4	Pressure sensor.....	19
2.7.5	12V battery.....	20
2.7.6	Raspberry Pi.....	21
2.7.7	NanoStationM NSM5 Wireless Access Point.....	24
2.7.8	MCP3008-I/P ADC.....	26
2.7.9	Resistors.....	27
2.7.10	Bread board.....	27
CHAPTER THREE: METHODOLOGY .....		29
3.0	Introduction.....	29
3.1	System requirements and Architecture .....	29

3.1.1	System Architecture.....	29
3.1.2	System requirements.....	30
3.1.3	Data and Requirement Analysis.....	30
3.1.4	Functional Requirements.....	31
3.1.5	Non-Functional Requirements.....	31
3.2	System Design.....	31
3.2.1	Billing system.....	33
3.2.2	Leakage and theft detection system.....	35
3.3	System Implementation.....	39
3.3.1	The metering system.....	39
3.3.2	The telemetric system.....	39
3.3.3	The billing system.....	40
3.3.4	The leakage and theft detection system.....	41
3.4	Testing and Validation.....	41
3.4.1	Unit Testing.....	41
3.4.2	System Integration Testing.....	42
3.4.3	Validation.....	42
4.0	CHAPTER FOUR: RESULTS AND DISCUSSIONS.....	43
4.1	Leakage and theft detection system.....	43
4.2	Metering and Billing.....	45
4.3	Validation of leakage and theft detection system.....	45
4.4	Discussions.....	46
5.0	CHAPTER FIVE: CONCLUSION, CHALLENGES AND RECOMMENDATIONS	
	48	
5.1	CONCLUSION.....	48
5.2	CHALLENGES.....	48



5.3 RECOMMENDATIONS .....	48
References.....	49
Appendix.....	52

## List of Acronyms/Abbreviations

AMI	Advanced Metering Infrastructure
Etc.	Et cetera
GIS	Geographic information system
GPS	Global Positioning System
GSM/GPRS	Global System for Mobile / General Packet Radio Services
NRW	Non-Revenue Water
NWSC	National Water and Sewerage Cooperation
RF	Radio Frequency
SCADA	Supervisory Control and Data Acquisition
VAT	Value Added Tax
WALOPU	Joint Water Loss Prevention Unit
WIS	Water Billing and Information System
WSD	Water Supplies Department
dll	Direct Link Library

## List of Figures

Fig. 2.1 Flow sensor.....	17
Fig. 2.2 Solenoid Valve .....	18
Fig. 2.3 1N4004 kickback diode and TIP120 .....	18
Fig. 2.4 Water turbine generator .....	18
Fig. 2.5 Pressure Sensor.....	19
Fig. 2.6 12V Battery.....	20
Fig. 2.7 Raspberry pi.....	21
Fig. 2.8 Raspberry Pi GPIO ports .....	24
Fig. 2.9 Ubiquiti M5 Access point.....	24
Fig. 2.10 ADC.....	26
Fig. 2.11 ADCSRA register and its corresponding bit positions.....	27
Fig. 2.12 Resistors and their color coding .....	27
Fig. 2.13 A bread board being used during the project development .....	28
Fig. 3.1 System architecture.....	29
Fig. 3.2 System Block Diagram.....	32
Fig. 3.3 Meter circuitry .....	33
Fig. 3.4 Billing flowchart.....	34
Fig. 3.5 Location of leakage point coordinates.....	37
Fig. 3.6 Leakages flowchart.....	38
Fig. 3.7 The metering system.....	39
Fig. 3.8 The telemetric system.....	40
Fig. 3.9 Billing server website .....	40
Fig. 3.10 Theft and leakage detection program .....	41
Fig. 4.1 Network with leakage.....	44
Fig. 4.2 Comparison between actual errors and derived error function.....	46

## List of Tables

Table 3.1 Meter components.....	32
Table 4.1 Leakage computation.....	43
Table 4.2 Validation of leakage and theft detection system .....	45
Table 4.3 Comparison of the system with the existing NWSC system .....	46

## List of Symbols

- $f_0, f_1$  Pipe friction factors without and with leakage
- $e$  pipe roughness
- $D$  pipe diameter
- $Q$  pipe flow
- $\Delta H$  Increment in pressure/head loss along path
- $A$  cross sectional area of pipe
- $g$  acceleration due to gravity
- $\Delta Q$  Increment in flow of water in pipe caused by leakage
- $Q_0$  Simulated flow in pipe derived by epanet
- $L$  length of pipe
- $L_1$  length from start node of pipe segment/pipe to leakage point
- $a, b, c, d$  start and end x, y coordinates of a pipe segment or pipe
- $x, y$  leakage coordinates
- $m$  gradient of pipe segment or pipe

# CHAPTER ONE: INTRODUCTION

## 1.0 Background of the study

Water is an essential resource for all nature to be able to sustain life and plays many important roles (MARTYUSHEVA, 2014). This resource is supplied to general public and most industries today through pipe networks which are one of the largest infrastructure assets of industrial society today (Poulakis, et al., 2003). These networks are interconnections of various components which are but not limited to transmission pipes, distribution pipes, service connection pipes, pumps, joints, valves, and fire hydrants.

The management of this vast process of supplying this resource which encompasses its extraction from a source, its transmission to a treatment plant, its treatment to desired quality standards, to its final distribution to the end user who can be an individual for domestic use or an industry for its day to day production schedule, is vested and entrusted to a water distribution company. National Water and Sewerage Cooperation (NWSC), a Government parastatal, is responsible for the distribution of Piped water to the general public in Uganda. The water utility manager or operator is tasked with planning, organizing, staffing, leading or directing, and controlling the organization to accomplish a goal. With the growth in population over the years, a strain on the water resource becomes paramount and entails this manager to derive ways on how to make sure that his resource is sustainably utilized. For such an enormous goal to be reached, optimization of these systems is done. Managers and water utility companies have also invested in many research methods that can help optimize systems today (Poulakis, et al., 2003; The Water Herald, 2014). This optimization covered by many research papers is categorised in four categories; reducing of costs of operation, loss of the precious resource, increase in precision of the whole process of operation and accuracy of measurements.

Conventionally, water meter reading and billing in many countries have largely followed a mechanical process where agents of the utility physically visit the premises of the users and manually record the consumption data for bill development and delivery for payment (MILLS, et al., 2012). This process has demerits of high operation costs to the utility companies which are through payments to the labour that takes the readings, over estimation of consumption readings at customers' premises when they are not at home, delay in

## References

ACS. 2010. *Utility Billing System*. 2010. p. 1.

ASSESSING PREPAY WATER METERING IN THE INFORMAL SETTLEMENTS OF WINDHOEK. Paul, Kastner, et al. 2005. 2005, An Interactive Qualifying Project Report, p. 29.

Audit Commission. 2008. *Customer Care and Billing System of the Water Supplies Department*. Hong Kong : Water Supplies Department, 2008.

Boulos, Paul F. and Wiley, Amanda N. 2013. *Automated Systems*. Broomfield, Colo. : Innovyze Ltd, 2013. pp. 20-22. <http://dx.doi.org/10.5991/OPF.2013.39.0015>.

Dhammika, De Silva, Mashford, John and Burn, Stewart. 2011. *Computer Aided Leak Location and Sizing in Pipe Networks*. 2011. pp. 10-12.

Elster. 2010. *Remote Shut-off Radio Valve*. 2010. p. 2.

EPRI, Electric Power Research Institute. 2007. *Advanced Metering Infrastructure (AMI)*. 2007. p. 1.

Heymans, Chris, Eales, Kathy and Franceys, Richard. 2014. *The limits and possibilities of prepaid water in Urban Africa: lessons from the field*. 2014. pp. 1, 6, 10.

KWESIGA, KATO EDITH. 2014. *Design and Simulation of an Automatic Water Leakage Detection System in a Pipeline*. Busia : Busitema University, 2014.

—. 2015. *Design and Simulation of an Automatic Water Leakage Detection System in a Pipeline (A Case of Kansanga Water Supply)*. Busia : Busitema University, 2015. p. 25.

MARTYUSHEVA, OLGA. 2014. *SMART WATER GRID PLAN B TECHNICAL REPORT*. FORT COLLINS, COLORADO : COLORADO STATE UNIVERSITY, 2014.

MILLS, GODFREY A., ACQUAH, MOSES A. and APPAH, BREMANG. 2012. *PHOTO ENCODING OF ANALOG WATER METER FOR USER ACCESS AND PAYMENT*

*SYSTEM*. Legon, Accra, Ghana : International Journal of Engineering Science and Technology (IJEST), 2012.

**Mugisha, Silver, Sanford V., Berg and Gaddi Ngirane, Katashaya. 2004.** *Short-Term Initiatives to Improve Water Utility Performance in Uganda: The Case of the National Water and Sewerage Corporation*. Kampala : National Water and Sewerage Corporation, 2004. pp. 2,5.

**Muzhir, Shaban Al-Ani, Rabah, Noory and Dua'a, Yaseen Al-Ani. 2012.** *Billing System Design Based on Internet Environment*. 2012. pp. 225-228.

**NATIONAL WATER AND SEWERAGE CORPORATION. 2012/13.** *ANNUAL ACTIVITY REPORT FOR THE FY 2012/13*. NATIONAL WATER AND SEWERAGE CORPORATION. Kampala : NATIONAL WATER AND SEWERAGE CORPORATION, 2012/13. Performance Review Report for Period July 2012-June 2013. NWSC-HQ/F&A-CP/GR/003.

**Oracle Utilities. 2009.** *Smart Metering for Water Utilities*. 2009. pp. 2-3.

**Poulakis, Z., Valougeorgis, D. and Papadimitriou, C. 2003.** *Leakage detection in water pipe networks using a Bayesian probabilistic framework*. Pedion Areos : Elsevier Ltd, 2003. 18 (2003) 315-327.

**Sensus. 2012.** *Bringing smart water networks into focus*. Raleigh : Sensus, 2012. pp. 1-36.

**Suresh, N., et al. 2014.** *RASPBERRY PI BASED LIQUID FLOW MONITORING AND CONTROL*. 2014. pp. 1-3.

**THARANYAA, J.P.SHRI, JAGADEESAN, A. and LAVANYA, A. 2013.** *THEFT IDENTIFICATION AND AUTOMATED WATER SUPPLY SYSTEM USING EMBEDDED TECHNOLOGY*. 2013. pp. 1-2.

*The Water Herald*. National Water and Sewerage Corporation (NWSC). 2014. 4, Kampala : National Water and Sewerage Corporation (NWSC), october-December 2014, Vol. 5.



UN-Habitat Lake Victoria Water and Sanitation Initiative team, National Water and Sewerage Corporation team. 2012. *Leakage Control Manual*. 2012. pp. 16-20.

water and sanitation program. 2008. *Developing Effective Billing and Collection Practices*. 2008.