INVESTIGATION OF NON-REVENUE WATER AND POTENTIAL ENERGY SAVING IN GREATER COLOMBO REGION

Nalin Thewarapperuma

(08/8613)

Degree of Master of Engineering

Department of Mechanical Engineering

University of Moratuwa
Sri Lanka

May 2013

INVESTIGATION OF NON-REVENUE WATER AND POTENTIAL ENERGY SAVING IN GREATER COLOMBO REGION

Nalin Thewarapperuma

(08/8613)

Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree

Master of Engineering

Department of Mechanical Engineering

University of Moratuwa

Sri Lanka

May 2013

DECLARATION OF CANDIDATE AND SUPERVISOR

I declare that this is my own work and this dissertation does not incorporate without acknowledgment any material previously submitted for a Degree or Diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis/dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date:

The above candidate has carried out Research for the Masters under my Supervision.

Signature of Supervisor: Date:

Abstract

The main purpose of this study is to identify critical factors influencing high non-revenue water percentage which directly affects energy usage in greater Colombo region. It also addresses finding methods to minimize the percentage of non-revenue water. This study was carried out through a data analysis where the energy related data and quantities of water production data were collected from Ambathale water Treatment Plant. The NRW data was collected from relevant officers involved in distribution systems of National Water Supply and Drainage Board.

This study only covers the greater Colombo region (Colombo city limits). All other regions have issues related to non-revenue water in different levels. Therefore, generalization of this specific sector results for other provinces may have limitations.

Analysis of Colombo city region statistics shows that the water supply entity in Sri Lanka (National Water Supply and Drainage Board) is unable to reduce the Non Revenue Water percentage in Colombo city region which results in higher energy loss in the water supply system.

Necessary recommendations and suggestions are made for the implementation of programs to reduce non-revenue water percentage for a significant figure in greater Colombo region since this region has the highest NRW percentage in Sri Lanka. Improvement of service level to consumers, optimization of operational efficiency, reduction of production costs by reducing of specific energy consumption of water and institutional developments are some of the factors that can be achieved.

Facilitating access to safe drinking water for people has great impact on socio-economic development in Sri Lanka. Therefore, results of this study may help to develop a program to reduce non-revenue water percentage in greater Colombo region and thereby reduction of electrical energy usage, while ensuring the safe drinking water for higher percentage of the population living in greater Colombo region.

Keywords: Non Revenue Water, Specific energy consumption, Water treatment.

ACKNOWLEDGEMENT

I am thankful to the University of Moratuwa for having offered me the opportunity to studying for the degree of Master of Engineering.

Without guidance, commitment and patience of Professor R.A. Athalage, Deputy Vice Chancellor University of Moratuwa, this dissertation would not have been realized. I wish to place on record my gratitude for him.

I am also thankful to Dr. A.G.T Sugathapala, who was the course coordinator and Dr. H.K.G.Punchihewa the present course coordinator for their support. NWSDB Higher management is gratefully remembered for the financial assistant granted and Deputy General Manager (Western Production) who is my immediate superior given me the flexibility for work to carry out my studies. I am grateful to all those who assisted me in this dissertation. My gratitude also goes to the staff of the Department of Mechanical Engineering.

I wish to record the undiminished encouragement from my wife, son and daughter throughout the preparation of this dissertation and for their support. I am grateful for all of them.

N. Thewarapperuma

May 2013

TABLE OF CONTENTS

Declaration of Candidate and Supervisor i
Abstract ii
Acknowledgement iii
Table of Contents iv
List of Figures vi
List of Tables vii
List of Abbreviations viii
List of Appendices ix
1. INTRODUCTION 1
1.1 Background of the Study 1
1.2 Identification of Problem 2
1.3 Objectives 4
1.4 Scope of Study 4
1.5 Methodology 5
1.6 Significance of the Study 6
1.7 Limitation of the Study 7
1.8 Chapter Outline 7
2 LITERATURE REVIEW 8
2.1 Introduction 8
2.2 Real Losses Performance Indicator 9
2.3 Real Losses or Physical Losses 12
2.4 NRW Levels Worldwide 13
2.5 Past Reports and Studies 15
2.5.1 Operations and system control study for the Greater Colombo Water Supply System (1987-1988) 15
2.5.2 Master Plan Update (1991) 15
2.5.3 Kalu Ganga Feasibility Study (JICA 1994) 16
2.5.4 Sri Lanka Third Water Supply and Sanitation Project (2000) 17
2.5.5 Detailed Design Study on Project for Reduction of NRW in the Greater Colombo Area (2001) 19

2.5.6 SAPROF Study 2007 21
2.5.7 Japanese Technical Cooperation for the Capacity Development Project for NRW Reduction in Colombo City 21
3 METHODOLOGY 23
3.1 Introduction 23
3.2 Conceptual Frame Work 23
3.3 Identification of the research area 23
3.4 Identification of Energy related and NRW related data to be collected 23
3.5 Method of Data Analysis 25
3.6 Summary 25
4 RESULTS AND DISCUSSION 26
4.1 Introduction 26
4.2 Ambatale water treatment plant 26
4.3 Analysis of NRW in Greater Colombo Region 29
5 CONCLUSION & RECOMMENDATION 33
5.1 Introduction 33
5.2 Summary of Findings 33
5.3 Conclusion 33
5.4 Recommendations 34
5.5 Future Work 36
Reference List 37
Appendix A: New Intake Flow 39
Appendix B: High lift Pumps 41
Appendix C: Details of Reservoir and Transmission from Ambathale WTP 42
Appendix D: Specific Energy – Ambathale WTP from 2008 - 2012 43
Appendix F: Existing Power Arrangement of Raw Water Intake 57

List of Figures

		Page
Figure 1.1	Monthly energy consumption in Ambatale WTP	3
Figure 1.2	Monthly Production Cost Ambatale WTP	4
Figure 1.3	Greater Colombo regions	5
Figure 2.1	Leak duration and volume	10
Figure 2.2	Run times of bursts on service pipes and mains	11
Figure 2.3	Key Influences on Annual Volume of Real Loss	12
Figure 4.1	Water balance for Colombo District	30
Figure 4.2	Chart of Colombo City Water balance and Value Cost	31

List of Tables

		Page
Table 2.1:	Capital Investment Program of NWSDB (Rs. Billion)	8
Table 2.2:	NRW as a share of water produced	13
Table 2.3:	NRW in cubic meters per network length	14
Table 2.4:	NRW Estimates and Values in Asia	15
Table 2.5:	Unaccounted for Water in Existing Service	16
Table 2.6:	Projected Water Loss Ratio in Kalu Ganga Feasibility Study (1994)	17
Table 2.7:	Estimated Average NRW July 1999	17
Table 2.8:	Distribution of Pipes - Material Wise - Colombo City	19
Table 2.9:	Age-wise Distribution of CI Pipes in Colombo City	20
Table 2.10:	Locations of Leakage Recorded in CI Pipes	20
Table 2.11:	Target Water Loss Ratio/UFW in SAPROF Study	21
Table 3.1:	Data Sources and Description of Data Acquired	24
Table 4.1:	Intake and High lift Pump details	26
Table 4.2:	Water production and Energy usage of High lift and Intake pumps	27
Table 4.3:	Energy usage and pumping quantity at Maligakanda & Ellie house	28

List of Abbreviations

Abbreviation	Description
ADB	Asian Development Bank
CBO	Community Based Organization
Cu. M.	Cubic Meter
GC	Greater Colombo
GOSL	Government of Sri Lanka
GWhr	Giga Watt hours
Km	Kilo Meter
LKR	Sri Lankan Rupee
Lpcd	Liter per Capita per Domestic
MDGs	Millennium Development Goals
MIS	Management Information System
NRW	Non-revenue Water
NWSDB	National Water Supply & Drainage Board
O & M	Operation & Maintenance
OIC	Officer In Charge
SEC	Specific Energy Consumption
SIV	System Input Volume
UN	United Nations
VSD	Variable Speed Drive
WTP	Water Treatment Plant

List of Appendices

Appendix	Description	Page
Appendix A	New Intake Flow	39
Appendix B	Highlift Pumps	41
Appendix C	Details of Reservoir and Transmission from Ambathale WTP	42
Appendix D	Specific Energy – Ambathale WTP from 2008 - 2012	43
Appendix E	Monthly Pumping Statistics	45
Appendix F	Existing Power Arrangement of Raw Water Intake	57

1. INTRODUCTION

1.1 Background of the Study

Access to safe drinking water has long been recognized as one of the main challenges of development. One of the key aims of Millennium Development Goals (MDGs) is to reduce the proportionate number of people, without sustainable access to safe drinking water by half of its present value by 2015 (Millenium Development Goals, 2005). For Sri Lanka achieving this objective is a great challenge. A crucial challenge found in developing countries to improve the coverage of water services is the ever increasing operational costs of the water supply systems mainly due to the high energy cost which is incurred in pumping systems. This issue has received considerable attention from the developed community. The issue of non-revenue water (NRW) perhaps received less attention, although it is also crucial to this matter. This dissertation study is focused on the non-revenue water (NRW) reduction aiming to save energy both from quantitative and qualitative measures.

The Sri Lankan National Water Policy stipulates that "Safe drinking water and access to sanitation services is a fundamental element" for the socio-economic development of the country. At present, nearly 34% of the national population has access to piped water though percentage is somewhat low. The national policy notes that "while coverage levels and service quality have improved markedly over the last decade, the need for water services has outstripped the government's ability to provide sufficient water for sanitation and ensure equitable access to the citizens throughout the country".

This policy points out that one of the important issues is the need for funds for capital investments for new water supply projects. In addition to these funding requirements, efficient operation and maintenance of the existing projects for minimal operational cost will also become an increasingly important issue in the future, especially with an increasing number of new water supply projects. Thus, with the current shortage in the government funding which is likely to be continued, it is essential that the operational costs of the water supply systems have to be minimized. It will not be possible for the Government of Sri Lanka to subsidize heavily the operation and maintenance costs for the services provided, as well as bear the high capital investment cost for all its projects.

In order to meet the challenge of minimizing the operational cost of the system, the main contribution factor has to be addressed. The main contributor is the energy cost which is used to drive the pumping systems since Sri Lanka has the highest electricity tariff in the South Asian region.

The NWSDB caters the greater Colombo region (Colombo city limits) from Ambatale water treatment plant which has a capacity of 524,000 m3/ day. Out of this production192,000 m3/ day is transmitted to greater Colombo region, even though there is a shortage of water supply to the Colombo city. Ambatale treatment plant has a huge energy consumption which is around 4.7GWhr per month. Most of the energy is used for pumping arrangements to different reservoirs at different locations in Colombo city. The surveys carried out by NWSDB and other independent organizations showed that non-revenue water percentage in Colombo city limits is high as 49% which is very high figure comparing to the Developed countries and some Asian countries. This implicates that almost half of the energy used in the treatment and the distribution process is wasted.

Thus saving of the non-revenue water quantity is equal to saving of energy used in the system. This study aims to find out the energy loss due to NRW in the selected area and to investigate the issues that are directly and indirectly related to increase in NRW in greater Colombo region and the possible measures that can be used to mitigate those findings. The scope of the study is limited to non-revenue water and the energy usage in greater Colombo region (Colombo city limits).

1.2 Identification of Problem

According to the production data at Ambatale water treatment plant, Appendix E shows that there is an average water production of 6,045,000 m3/month for the Colombo city. Also MIS reports show the average water sales in Colombo city limits as.3,337,000 m3/month. Therefore it is obvious that there is a water imbalance due to NRW.

The contributing factors for the NRW are,

- Physical losses.
- Unauthorized consumption.
- Meter errors.
- Unbilled authorized consumption.

Therefore it implicates that the NRW in greater Colombo area is significantly high. Also the data given in the Figure 1.1 shows that the energy consumption in Ambatale water treatment plant is considerably high. Therefore it can be identified that the high NRW directly affects the high energy cost and the reduction of NRW is a great advantage of saving energy which will be benefited for the whole country. The Figure 1.2 shows that the major component of the operational cost of Ambatale water treatment plant is the energy cost.

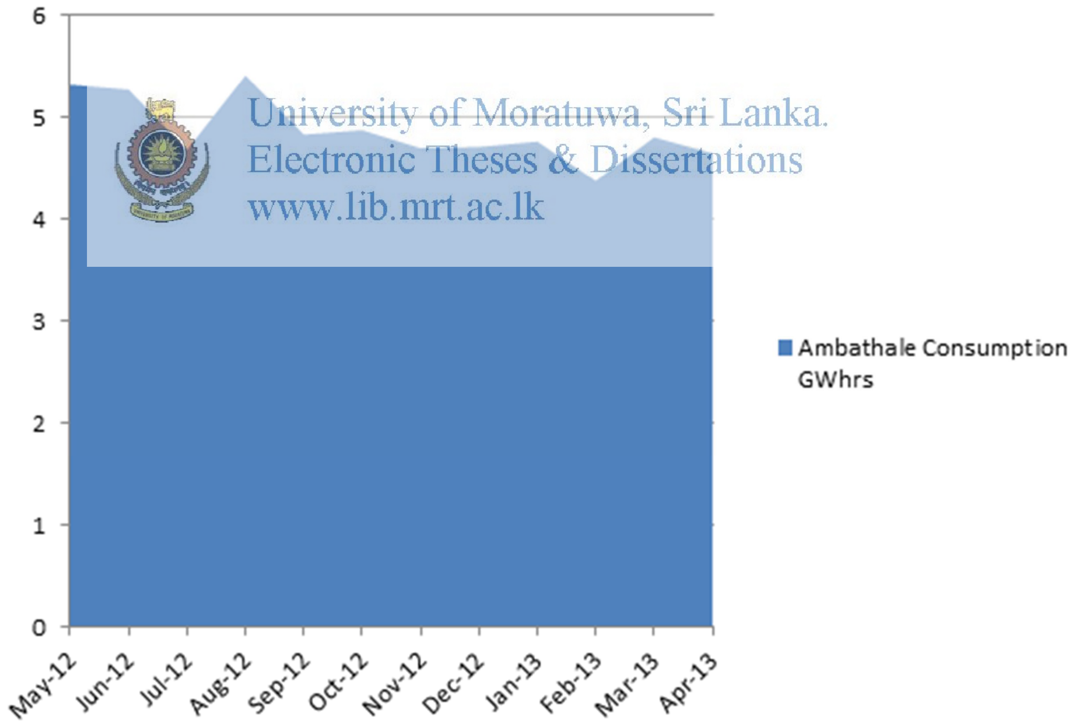


Figure 1.1 Monthly energy consumption in Ambatale WTP

Source: National Water Supply & Drainage Board, 2012

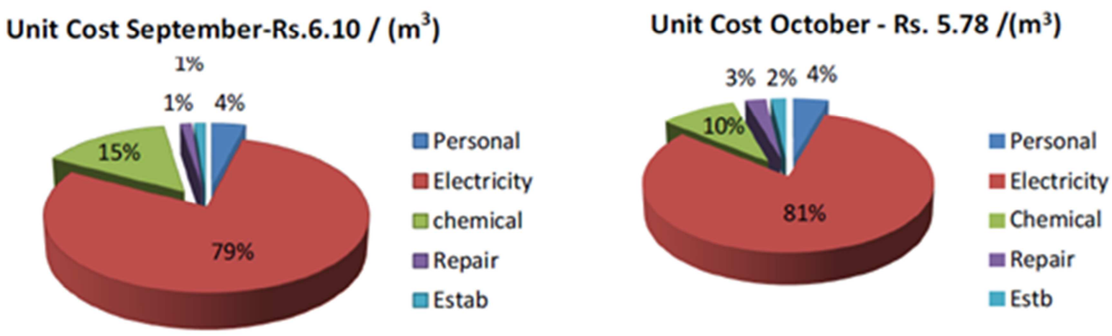


Figure 1.2 Monthly Production Cost Ambatale WTP

Source: National Water Supply & Drainage Board, 2012

1.3 Objectives

The aim of this research is to study the effect and impact of non-revenue water on energy saving in the greater Colombo region. Accordingly, make suggestions to reduce NRW in long term and short term basis. In the process, this research has attempted to achieve the following objectives in order to meet its aim.

a. To analyze the energy usage in Ambatale water treatment plant to identify the energy loss due to NRW.
b. To analyze the present situation of non-revenue water in greater Colombo region.
c. To identify key factors affecting the non-revenue water.
d. To recommend guidelines for reduction of non-revenue water in greater Colombo region.

1.4 Scope of Study

This study mainly focuses on finding the ways that accounts to high NRW in greater Colombo area (city limits) and the relationship between NRW and the energy usage in greater Colombo region of NWSDB. Further, it identifies that the methods are being used to reduce NRW in other countries and the most appropriate methods that can be adopted in our context.

1.5 Methodology

The study area for this research is selected as NRW in greater Colombo region since it has the highest NRW percentage comparing to the other regions in Sri Lanka. The greater Colombo region covers the Colombo city limits which is given in Figure 1.3 and represents 34% of total consumers in NWSDB. The study would cover the analysis of Energy usage in Ambatale water treatment plant, present situation of NRW in greater Colombo region, Identification of factors affecting high NRW and also recommendations for reduction of NRW and energy usage accordingly.

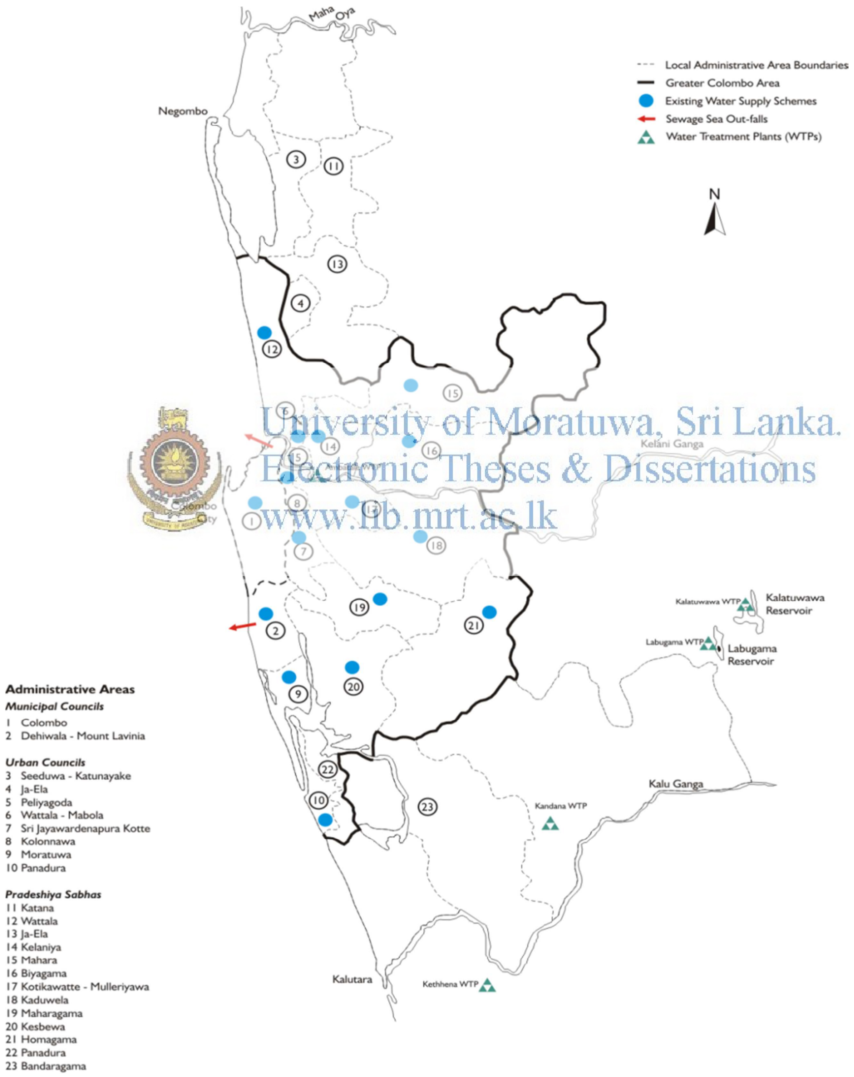


Figure 1.3 Greater Colombo regions

Source: National Water Supply and Drainage Board, 2012

The data comes from what is available in the NWSDB, which can be used:

- To analyze the energy usage in Ambatale water treatment plant and it's component related to greater Colombo region.
- To analyze the present situation of NRW in greater Colombo region
- Understand the constraint and issues pertaining to the present situation.
- Make decisions for the changes needed in the existing operation and maintenance system.

To collect the required data and information, the reports which were written on earlier researches on NRW, annual reports of NWSDB, Field data collected by NWSDB, will be used. The data will be thoroughly checked, edited and tabulated to make the data set for analysis. Data processing will be performed with the help of a calculator, a personal computer and other electronic and manual devices.

In this study, both quantitative and qualitative methods will be used to analyze the data and information. Presentation of produced data will be used in tables, necessary maps and diagrams whenever appropriate. After analyzing the data and information, conclusion will be made with the recommendation for reduction of NRW in greater Colombo region subsequently the reduction of electrical energy usage in water treatment and distribution process.

1.6 Significance of the Study

Water is recognized as one of the most important basic needs of the people. Provision of safe drinking water in adequate quantities is the present requirement of the people. The public water supplies are in operation to meet the changing requirements of the consumers. Subsequently, the availability of quality drinking water has become a prominent issue of the day. The government is committed to improve the standard of living, promote economic prosperity and preserve the environment by providing access to safe drinking water for an affordable price to the people of Sri Lanka.

To address this issue NWSDB need to supply an adequate quantity to meet the demand with or without having new treatment plants with ensuring the sustainability of water supply services. To achieve this goal without putting up new treatment plants the only way is to reduce NRW component so the affordability of the consumer and sustainability of the institution will be realistic as energy usage (the major component of the expenditure) in the water supply process will be minimized.

This challenge can be achieved by theoretical approach of reducing NRW. This theoretical approach is not applicable in real world due to practical difficulties. Therefore the theoretical approach should be further developed with the analysis of empirical evidence gathered from literature survey and the research outcome.

This study examines and explains the characteristics and the significance of factors that exist and how to develop a sustainable method to reduce NRW and the optimization of the energy usage.

1.7 Limitation of the Study

This research is a result of years of research which brought the author closer and closer to the water sector in western province.

The selected area for the research is the greater Colombo region which is considered to be the area which has the highest NRW in Sri Lanka. Also the most populated area in Sri Lanka. Since the most of the energy used by NWSDB is coming under this greater Colombo region it is felt that the limitation is worth.

It is felt that more research is required in the field of energy saving through NRW reduction in the local context and in the region. This will generate more information and contribute towards more knowledge.

1.8 Chapter Outline

This chapter has given the background to the research. It has introduced the subject of study and set down the objectives of the research. It gives a brief of water supply situation in Sri Lanka and operational aspects of the National Water Supply & Drainage Board (NWSDB). This helps to understand the existing NRW figures and the energy usage in greater Colombo region. Finally this chapter gives a foresight of the other chapters that follow. Chapter two, which follows, contains the literature review, which deals with the theoretical and empirical aspects for the subject matters of the research.

2 LITERATURE REVIEW

2.1 Introduction

National water supply and drainage board was established in 1975 and is the principle and sole national agency responsible for developing and operating water supply and sewerage systems in Sri Lanka. It had its origin as a sub department of the public works department. In 1965, it became a division under the ministry of local government. Subsequently, several major urban water supply schemes operated by local authorities were transferred to improve coverage and service delivery

Millions of people in Sri Lanka do not have access to adequate water supply. Sri Lanka's present pipe –borne water supply coverage stands at 39%. Out of this figure NWSDB schemes account for 31%, while approximately 8% are local authority and small community water supplies managed by CBOs. Hand pumps, tube wells accounts for 8% of the population. Dug wells are utilized by 32% of the population. Other sources such as rain water harvesting, safe natural springs account for 2%. Accordingly the current water coverage is 81%.

The capital investments required to achieve the pipe borne water coverage outlined in the corporate plan for the period 2012 -2016 are given in Table 2.1.

Table 2.1: Capital Investment Program of NWSDB (Rs. Billion)

Year	**Investment Required (Water)**	**Investment Required (Sewerage)**
2012	57.457	15.639
2014	70.820	22.717
2014	82.225	19.809
2015	63.394	10.810
2016	35.374	7.914
Total (2012-2016)	**309.270**	**76.889**

Source: National Water Supply & Drainage Board

Accordingly, an investment of Rs. 309,270 million is required for the five- year period, which averages Rs. 77.2 billion annually. But the capital investment available for 2014 from the sources, that is GOSL and donor funding in the NWSDB budget for 2014 amounts to only Rs, 40.22 billion which is 38%of the requirement Lack of adequate water supply retards opportunities for growth in industry and employment, and heightens the vulnerability to water borne diseases and public health hazards. Therefore reduction of NRW is a must in order to have the existing supply available to more consumers.

Non-revenue Water can be classified as NRW in Distribution systems and NRW in transmission systems. NRW in distribution systems is the volume of water that has been input to the distribution system and is "lost" before it reaches the customer. Losses can be real losses, referred to as physical losses through pipe line leaks and apparent or commercial losses through or metering inaccuracies. High levels of NRW are detrimental to the financial viability of water utilities, as well as to the quality of water itself. NRW is typically measured as the volume of water lost as a share of net water input. However it is sometimes also as the volume of water lost per km of water distribution network per day. The transmission system NRW is occurred mainly due to the physical losses through pipe line leaks [1].

2.2 Real Losses Performance Indicator

The common practice of expressing losses as a percentage of System Input Volume (SIV) has been officially rejected by national technical working groups in the UK,USA, Germany and South Africa. The reason for this rejection is that losses expressed as a percentage are so strongly influenced by differences and changes in per capita consumption and industrial consumption and consumption has no significance in respect to losses. The office of water service, a UK government body regulating the water industry (OFWAT), the economic regulator for England and Wales, has also reached the same conclusion. The preferred performance indicators for comparing Leakage Management Performance is to quote the total level of real losses obtained from the annual water balance in terms of liters per connection per day per meter of pressure when the system is pressurized. (l/conn/day/m.w.s.p)

This performance indicator has the advantage of taking in to consideration the key factors that affect the level of leakage in any system, namely the system pressure and the quantity of network subject to that pressure. By using this performance indicator it is possible to assess how well a particular water distribution operator is dealing with the technical aspects of infrastructure management, maintenance and active leakage control.

The application of active leakage control also contributes significantly to constraining the annual volume of losses. In Colombo city, active leakage control does not take place. Small bursts may go undetected and will run for months, if not years, before finally developing on to a major event that is reported to the utility because it is causing disruption of supply or is causing damage to other infrastructure such as roads.

Time makes a difference; the longer a leak runs the greater the volume of water that is lost. Fig 2.1 shows the three key factors in amount of water lost from an individual leak on burst- awareness time (A) location time (L) and repair time (R) [14].

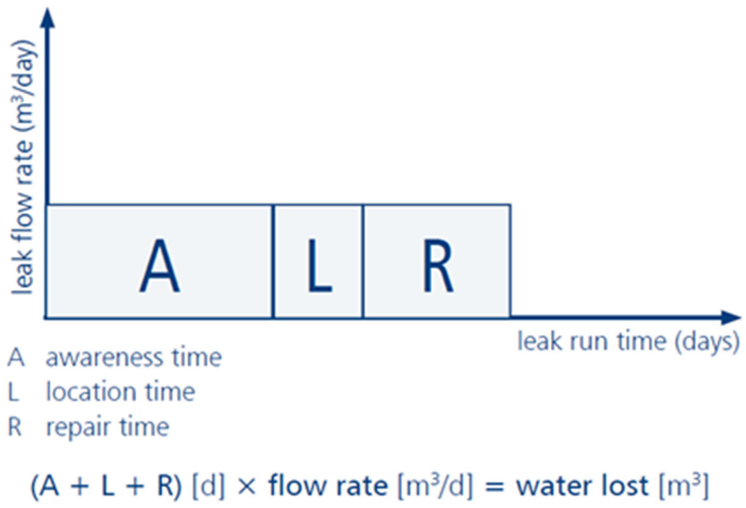


Figure 2.1 Leak duration and volume

Source: Location and Repair Guidance Notes IWA, 2007.

Bursts with high flow rates do not produce the largest volumes of real losses or leakage as the run time is the key factor. Figure 2.2 shows typical run times for a reported main burst, a reported service connection burst and an unreported service connection burst.

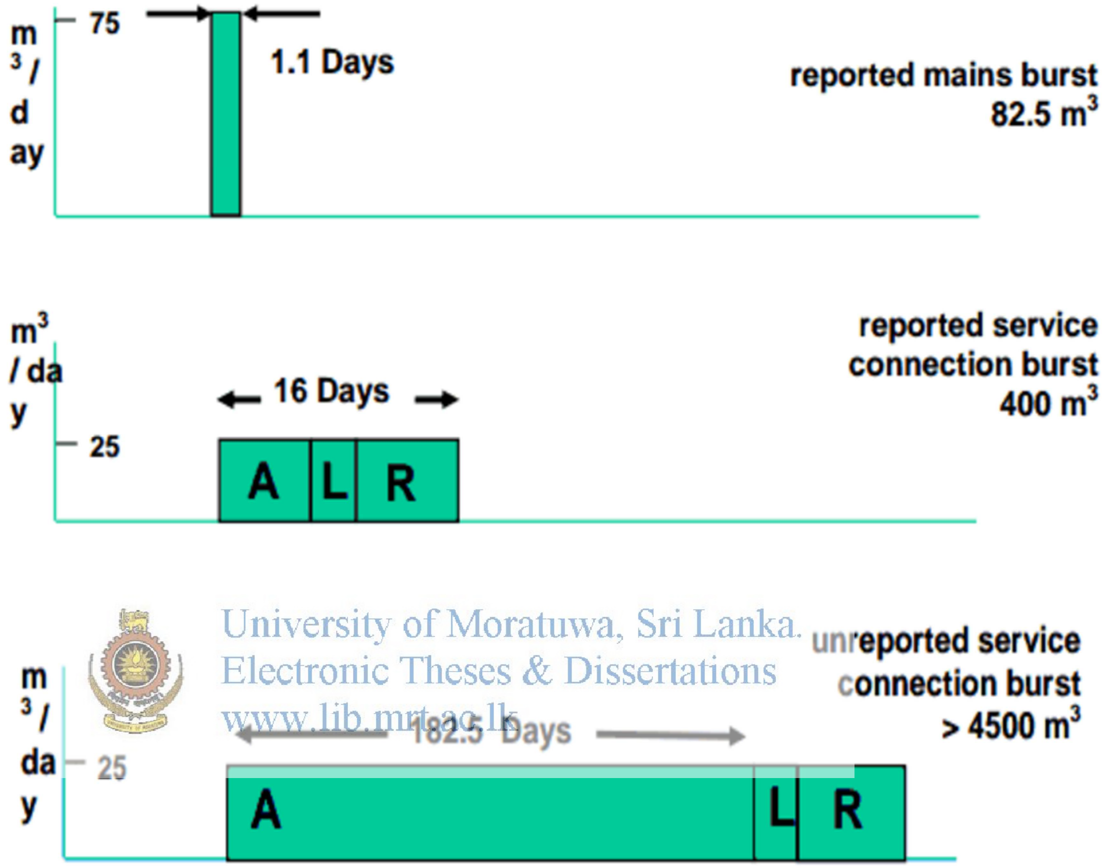


Figure 2.2 Run times of bursts on service pipes and mains
Source: Location and Repair Guidance Notes IWA March 2007.

The speed and quality of repairs directly affects the annual volume of losses. When poor quality materials are used, repeat burst events associated with failure of the repair material are common. Using high quality materials and carrying out repairs quickly lead to a two-fold benefit for the management of losses. All water distribution networks deteriorate with time. This accepted fact dealt with a well-managed system by the implementation of an annual infrastructure rehabilitation program. The aim of such programs is to replace a certain percentage of the network typically a minimum of 2% (or more in funds allow) per year [11].

2.3 Real Losses or Physical Losses

To the Leakage Practitioner there are four key Leakage Management Activities that can constrain the Annual Volume of Real Loss, namely:

- Pressure Management
- Infrastructure Management
- Active Leakage Control
- Speed and Quality of Repairs

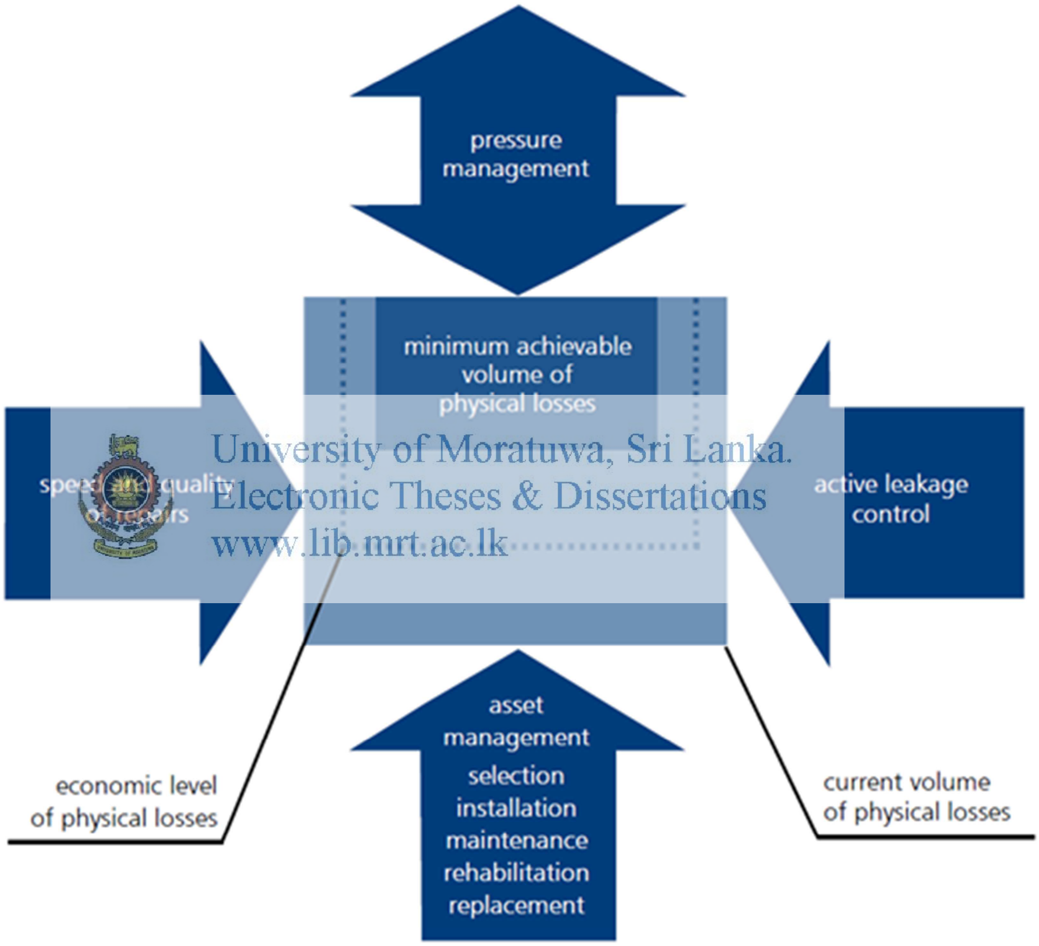


Figure 2.3 Key Influences on Annual Volume of Real Loss

Source: Location and Repair Guidance Notes IWA March 2007.

2.4 NRW Levels Worldwide

Different countries use different indicators to express the NRW. Most common way is the percentage of NRW express as a share of water produced. The countries which use this indicator and percentages of NRW are given in Table 2.2.

Table 2.2: NRW as a share of water produced

Country	NRW
Singapore	5%
Denmark	6%
Netherlands	6%
Germany	7%
Japan	7%
Philippines	11%
Tunisia	18%
England	19%
France	26%
Bangladesh	29%
Italy	29%
Chili	34%
Indonesia	39%
Mexico	51%
Nigeria	70%

The countries use to express NRW in cubic meters per network length (m3/km) are given in Table 2.3.

Table 2.3: NRW in cubic meters per network length

Country	**NRW %**
Netherlands	1.5
Denmark	1.6
Germany	2.4
Australia	4.4
Portugal	7.0
England	10.0
Russia	20.0
Scotland	21.3
Ireland	29
Brazil	42
China	52
Netherlands	1.5
Denmark	1.6
Germany	2.4
Australia	4.4
Portugal	7.0

Table 2.4: NRW Estimates and Values in Asia

Region	Urban Population with Service Connections (in Millions)	l/c/d	System Input Volume	%	Non-Revenue Water	Physical Losses	Commercial Losses (billion m3/year)	NRW	Value billion $/year
Central & West Asia	29	450	13,050,000	40	5,220,000	1.4	0.5	1.9	0.6
East Asia	605	230	129,150,000	25	34,787,500	9.5	3.2	12.7	3.8
Middle East	167	250	41,750,000	30	12,525,000	3.4	1.1	4.5	1.4
South Asia	202	180	36,360,000	35	12,726,000	3.5	1.2	4.7	1.4
Southeast Adia	133	280	37,240,000	35	13,034,000	3.6	1.3	4.9	1.5
Total Asia	**1,136**		**267,550,000**		**78,292,500**	**21.4**	**7.3**	**28.7**	**8.6**

Source: Urban Population: WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation 2006 Data. NRW estimates: Roland Liemberger

2.5 Past Reports and Studies

There have been many studies since the Master Plan 1972 until the latest JICA funded Japanese Technical Cooperation for the Capacity Development Project for Non Revenue Water Reduction in Colombo City 2011. An outline of some of these studies are discussed here.

2.5.1 Operations and system control study for the Greater Colombo Water Supply System (1987-1988)

This study was the first ever study focused on leak detection and repair. It was implemented with pilot studies and NWSDB commenced leak detection activities. Subsequently mapping activities of the Greater Colombo System also commenced.

2.5.2 Master Plan Update (1991)

The 1991 Master Plan Update as shown in Table 2.5 assumed an average of UFW to be 39.8% of the water supplied to the existing service areas including Colombo City and 25.0% for new areas. It was then considered reasonable that by 2020, UFW could be reduced to 20.0% in both new and existing areas, taking into account the efforts NWSDB was making to reduce NRW. However, the past and present records show that this target was not achieved in CMC and in most of the adjoining areas.

Table 2.5: Unaccounted for Water in Existing Service

NWSDB Water Supply Zone	**Unaccounted for Water (% of Supply)**
Colombo 1 - Maligawatta	46.2
Colombo 1 – Peoples Park	
Colombo - 2	
Colombo - 3	
Dehiwala	21.3
Kotte	
Moratuwa	46.2
Panadura	19.1
Kolonnawa	21.3
Mulleriyawa	35.0
Kelaniya (4)	
Horana	
TOTALS	39.8

Source: NWSDB

2.5.3 Kalu Ganga Feasibility Study (JICA 1994)

The projected water loss ratios estimated in the Kalu Ganga Feasibility Study are shown in Table 2.6.

Table 2.6: Projected Water Loss Ratio in Kalu Ganga Feasibility Study (1994)

Service Area	1995	2000	2005	2010	2015
Existing Service Area					
Colombo M.C.	40%	35%	35%	35%	30%
Other Areas	30%	25%	25%	25%	20%
New Service Area	As initial ratio = 10%, subsequently increasing in straight line projection				20%

Source: Kalu Ganga Feasibility Study (1994)

These predictions were at moderate level, and were accompanied by an intensive initial effort to succeed, but the CMC area did not achieve the results expected. Other areas require further evaluation. However, these predictions are considered to be within practical limits.

2.5.4 Sri Lanka Third Water Supply and Sanitation Project (2000)

In July 1999, NWSDB estimated the NRW within the Colombo City area to have the components and percentages as shown in Table 2.7 below. This was a very comprehensive study which covered almost all the aspects of NRW.

Table 2.7: Estimated Average NRW July 1999

Component	Description	Percentage (%)
Metering Errors	Apparent discrepancies between produced water and revenue water	3
Illegal connections	Bypasses, reconnected disconnections and completely illegal connections	7
Tenement gardens	Legal unbilled connections to standpipes in tenement garden areas	15
Housing schemes	Leakage within tanks, etc. in housing schemes	3
Leakage	In distribution mains	23
Total		51

Source: NWSDB

The study made the following observations on the component losses of NRW:

a. Distribution System Leakage
   - Inadequate cover to service connections
   - Damage by other service contractors
   - Lack of skilled workman to do repairs due to lack of proper training
   - Inadequate materials and equipment to do the repair to a high standard

b. Illegal Connections
   Information provided by NRW section of NWSDB estimated that about 20,000 illegal connections existed in the CMC area.

c. Unbilled Legitimate Consumption
   - It was estimated that around 300,000, almost 40% of CMC population (2001) lived in tenement garden areas using around 37,000 m3/day (based on 8.5 m3/connection/day)
   - Water is lost in housing schemes owing to poorly maintained plumbing and due to lack of ball valves in roof tanks and ground tanks.

d. Administrative Losses
   - Estimated meter readings
   - Meter misreading
   - Transcription errors
   - Error in estimated unmetered consumption
   - Delay in issuing first bill after installation of a water meter

In addition, the study made the following observations/recommendations with regard to Operations and Maintenance of CMC area:

e. Customer complaints should be recorded for each operational zone and be reviewed regularly by senior operational managers. The details should include:
   - Address of complaint,
   - Type of problem
   - Exact site location.
   - Details of complaint including dates, times at which incidents occurred
   - The cause of the problem
   - Details of action taken (if known)

f. Full details of all mains failures and repairs must be accurately recorded. This includes:
   - Material and diameter of the main
   - Location and time of the failure
   - Probable reason for the failure
   - Details of the repairs carried out

g. Currently valve operations are carried out by operations staff in the CMC area without reference to superior officers and without creating an auditable paper trail to track changes. Operational events must be recorded, as this may enable a history of customer complaints against operational changes to be identified. Such changes include:
   - Valve changes
   - Major changes in flow direction
   - Re-zoning and installation of valves

2.5.5 Detailed Design Study on Project for Reduction of NRW in the Greater Colombo Area (2001)

This study revealed comprehensive details of the existing distribution system with composition of pipe materials, with their age and the requirement of pipe replacements. The details of composition of pipe network are based on this information.

Table 2.8: Distribution of Pipes - Material Wise - Colombo City

Pipe Material	Length(km)	% Share
Cast Iron(CI)	491,291	96.7
Ductile Iron (DI)	8,609	1.7
PVC	6,822	1.4
Asbestos Cement(AC)	740	0.1
Steel(MS)	600	0.1
Total	508,062	100

Source: Detailed Design Study by NSC 2001

The majority of the pipes are cast iron and 77% are more than 50 years old. The distribution of cast iron by age is shown in Table 2.9.

Table 2.9: Age-wise Distribution of CI Pipes in Colombo City

Age	Percentage %
Over 100years	22
70-100 yrs.	47
50 -70 Yrs.	8
20 – 50 Yrs.	22
Less than 20 years	01

Source: detailed Design Study by NSC 2001

The condition of these pipes, and their appurtenances, as could be expected, is far from satisfactory.

The study has further established the composition of the type of leaks from old CI mains and appurtenances as shown in Table 2.10.

Table 2.10: Locations of Leakage Recorded in CI Pipes

No.	Leak Location	Number of Leaks
1	Body of the Pipe	852
2	Joint	449
3	Hydrants	71
4	Valves	209

Source: detailed Design Study by NSC 2001

It is noted as a conclusion that the approach of most of the project studied and the construction works undertaken appear to concentrate primarily on the reduction of present level of leakage. But, NRW management should be viewed and endeavored holistically to achieve sustainable good results.

2.5.6 SAPROF Study 2007

SAPROF study subsequently considered slightly lower projected water loss ratios in the water demand projection shown in Table 2.11.

Table 2.11: Target Water Loss Ratio/UFW in SAPROF Study

Area	**Percentage of Water Loss/ UFW**					
	1995	**2000**	**2005**	**2010**	**2015**	**2020**
Existing Areas						
Colombo MC	40%	36%	32%	28%	28%	28%
Other existing areas	25%	23%	21%	20%	19%	18%
New areas	10%	11%	12%	13%	14%	15%
Overall for Greater Colombo	32.4%	28.2%	24.0%	21.3%	20.6%	20.3%

Source: SAPROF Report

These predicted UFW ratios were relatively too stringent and warranted very high and intensive effort to continue which was generally at the threshold of practical limits. Current records show that the CMC area did not achieve the results expected: other areas are to be further evaluated.

2.5.7 Japanese Technical Cooperation for the Capacity Development Project for NRW Reduction in Colombo City

JICA conducted this Pilot Project in response to a request from the Sri Lankan Government to prepare an effective and affordable NRW reduction plan. The project was initiated in November 2009 and the final report was submitted in October 2012.

Expected Output

The basic purpose of the project was to strengthen NWSDB's capacity to implement NRW reduction activities in Colombo City. The following two outputs are expected:

Output 1: Management capacity of senior officers of Regional Center (Western-Central) to plan and supervise NRW reduction activities is enhanced

Output 2: Technical and operational capacity to control NRW reduction activities by officers/staff of Western-Central Regional Centre is developed

Pilot Projects Implemented

In this context, two target areas were selected in Kotahena (OIC 2) and Borella (OIC 4). The Pilot Project planned and implemented a series of NRW reduction activities including pipe replacement. Officers/staff of Western-Central Regional Centre have cooperated closely during the project activities and their capacity to plan and execute such projects in the future has been strengthened. The pilot study in Borella area confirmed that 3 of the 6 Pilot areas were isolated and the final NRW determined.

Equipment Provided to RSC(W-C), NWSDB

Modern NRW detection equipment has been introduced and utilized throughout the project and the equipment handed over to Western-Central (WC) Regional Support Centre (RSC) upon project completion.

The Results of the Study

The results and findings of the study were as follows:

- Isolation of the existing system proved very difficult due to the complexity of the network and lack of accurate mapping of assets.
- It is not possible to implement a system-wide Active Leakage Control Strategy without system upgrades
- Many valves within the system are missing or buried
- Existence of ‘bundled pipes’ within the system is a major cause of the NRW in the CMC area.

The pilot study did not cover the entire aspects of apparent losses in the NRW reduction management. It was an initial study conducted to assess the current status of the existing CMC distribution system with respect to its suitability, difficulty, and prevailing complexity for forming DMAs as tools to manage NRW in a systematic way, as well as to identify the needs of general system upgrades and modifications.

3 METHODOLOGY

3.1 Introduction

This chapter contains the research methodology adapted to finalize the theoretical and empirical parts of the study contained in Chapter 2.The method of data collection and analysis are discussed later in this chapter.

The study focuses on finding the relationship between Energy usage and the NRW in the greater Colombo region. The frame work is developed to find the solutions for the above mentioned problems based on the following objectives. (1)To analyze the present situation of NRW and the energy usage in greater Colombo region, (2) to identify key factors affecting the NRW and energy usage and (3) to recommend ways and methods to reduce NRW thereby energy usage.

3.2 Conceptual Frame Work

The conceptual frame work developed for the study can be classified as identification of the area which the research to be implemented, identification of the data of both Energy related and NRW related, Collection of data, and the data analysis.

3.3 Identification of the research area

The research area has been identified as the area which has the highest NRW percentage and also the most populated area in Sri Lanka. This will give the highest impact to the research so that the energy savings will be high. Therefore the area was selected as Greater Colombo region (Colombo city limits).

3.4 Identification of Energy related and NRW related data to be collected

Following data sources were extensively used to obtain the data for this research.

The main energy user which is related to the water supply to the Colombo city limits is the Ambatale Water Treatment Plant. Therefore the data related to this research was identified as

- Monthly power consumption both kWh and kVA of the treatment plant
- Monthly power consumption related to greater Colombo water supply both kWh and kVA

- Specific energy consumption.
- NRW data of the greater Colombo region.
- Relevant Pump details.
- Characteristic curves of the relevant pumps.
- Actual monthly total water production at Ambatale WTP.
- Actual monthly water production to the greater Colombo region.
- Water sales values in the targeted area.

The table 3-1 shows the nature and description of data acquired from different data sources that were used to conduct this research. The data gathering in relating to energy usage and the water production at Ambatale WTP was not difficult since the author is attached to the Ambatale WTP at the capacity of Manager (Maintenance). Therefore the accuracy of data could be guaranteed.

Table 3.1: Data Sources and Description of Data Acquired

Data Source	Description and Nature of Data
Management Information Reports	Non-Revenue Water details for year 2008, 2009 and 2010.
Monthly power consumption at Ambatale WTP	Total electricity usage at WTP with kWh and kVA and Energy usage for grater Colombo water supply
Pump and characteristic curve details	Related pump (Ellie house pumps, Maligakanda pumps, New Ellie house pumps, Intake pumps) details such as Head, Capacity, motor power, NPSH, Efficiency, etc,.
Actual monthly water production at Ambatale WTP.	Total production at the plant and the quantity produced to greater Colombo region. (monthly production reports)

3.5 Method of Data Analysis

The data analysis part was done by using a computer looking at the format and the size of the data collected, it was apparent that a computer would have to be used to analyze the data.

This was mainly due to the fact that the computer is a tool that can be quickly handling complicated statistical and mathematical calculations on huge amounts of data and then display results in graphical and table forms.

3.6 Summary

Chapter 3 introduced a conceptual framework to find a solution for problem defined in this study. The data analysis was developed in the conceptual frame work based on the objectives formed in the Chapter 1.The input data required were defined and output of each section also was described.

Further, this chapter has explained the source and description of data and the method of data analysis.

4 RESULTS AND DISCUSSION

4.1 Introduction

The previous chapter outlined the objective and the methodology used for the research. This chapter provides an overview of the information collected, a description of the analytical techniques employed, the accompanying statistical analysis and the resulting research findings. These discussions have taken into consideration, the conceptual methodology discussed in Chapter 3.

4.2 Ambatale water treatment plant

Ambatale water treatment plant was commissioned in 1965. This is the largest intake and water Treatment plant in Sri Lanka. It consists of three water treatment plants known as Main plant, New plant and Seta plant. Three intakes along Kelani River at Ambatale named as Old intake, New intake and Seta intake that consists of thirteen pumps (13) supply raw water to the Ambatale WTP. Appendix A gives the pumps arrangements in the Ambatale intake. The design capacity of the WTP is 524,000 m3/ day to the system. Appendix E gives the monthly production data of Ambatale WTP. The Treatment plant transmits water to five reservoirs located at different places namely Maligakanda, Ellie house, Dehiwala, Jubilee, Kolonnawa Appendix C gives the existing transmission system of Ambatale WTP. The details of those high lift pumps and intake pumps are given in the Table 4.1.

Table 4.1: Intake and High lift Pump details

Description	Flow m3/hr	Head (m)	Power (kW)	Efficiency (%)
Old Intake 1	3,860	25	355	81
Old Intake 2	3,860	25	355	81
Old Intake 3	3,860	24	340	81
Old Intake 4	3,860	24	340	81
New Intake A	3,800	27.7	400	82
New Intake B	3,800	27.7	400	82
New Intake C	3,800	27.7	400	82
New Intake 1	2,250	27.7	172	80

New Intake 2	2,268	25	220	80
New Intake 3	2,268	25	220	80
New Intake 4	2,390	28	185	80
Maligakanda	1730	86	570	79
Ellihouse	1270	106	460	78
New Ellihouse	920	86	320	81

Source: National Water Supply & Drainage Board Ambathale

The water treatment plant is operating almost at the full capacity throughout the year. The huge electrical energy is used to run the treatment plant and the major portion is consumed by the intake and high lift pumps. The Table 4.2 gives the average water production and the energy usage of the said pumps.

Table 4.2: Water production and Energy usage of High lift and Intake pumps

Month	Water Prod. (m3)	kWh	kVA
2012 May	16,755,262	5,323,977	9,759
2012 June	14,489,603	5,275,011	9,759
2012 July	14,493,388	4,686,117	9,125
2012 August	15,801,334	5,415,128	9,737
2012 September	14,712,812	4,834,522	8,074
2012 October	14,956,302	4,878,094	8,279
2012 November	14,530,740	4,701,590	8,894
2012 December	14,447,329	4,713,368	7,625
2013 January	14,536,832	4,766,023	8,024
2013 February	13,377,950	4,377,975	8,180
2013 March	14,808,052	4,808,531	7,848
2013 April	14,521,791	4,650,359	7,735

Source: National Water Supply & Drainage Board

Out of these high lift pumps, only Maligakanda and Ellie house pumps are used to pump water to the greater Colombo distribution system. There are three same capacity pumping sets connected in parallel to the pumping main. Two pumps are running continuously while the other one is on standby used to pump water to Maligakanda reservoir. There are four same capacity pumps connected in parallel to the Ellie House pumping main. Out of these four pumps, three pumps are running continuously while one is on standby. There are two same capacity pumps which are located in a different pump house connected in parallel, used to pump water to the same Ellie house reservoir. In this system also one pump is running continuously while the other one is on standby. The energy usage and the water pumping quantity of Maligakanda and Ellie house pumps are given in the table 4.3.

Table 4.3: Energy usage and pumping quantity at Maligakanda & Ellie house

Month	**Maligakanda (m3)**	**Ellie House (m3)**	**Total for Colombo city (m3)**	**kWh**
2012 May	2,542,930	3,156,978	5,699,908	
2012 June	2,484,930	3,200,520	5,685,450	
2012 July	2,559,701	3,207,074	5,766,775	
2012 August	2,645,137	3,247,033	5,892,170	
2012 September	2,657,070	3,164,190	5,821,260	
2012 October	2,784,327	3,352,898	6,137,225	
2012 November	2,709,210	3,062,790	5,772,000	
2012 December	2,716,747	3,233,486	5,950,233	
2013 January	2,594,204	3,148,701	5,742,905	1,471,600.00
2013 February	2,544,500	3,011,792	5,556,292	1,398,600.00
2013 March	2,852,837	3,237,361	6,090,198	1,484,700.00
2013 April	2,742,090	3,263,730	6,005,820	1,439,200.00

Source: National Water Supply & Drainage Board

From this table it is possible to calculate the average monthly electricity consumption and the average monthly water production of the Greater Colombo region. i.e Maligakanda and Ellie house pumping quantity and the energy usage for those pumps. The intake energy usage is given as a total value. Therefore the energy used for pumping for greater Colombo area has to be calculated as proportions of the water quantities.

Average Monthly water production at Ambatale WTP = 14,746,831 m3

Average monthly water production for Colombo city area = 6,138,000 m3

Considering the plant loss as 4%, this ratio can be applied to average monthly water pumping quantity from the intake.

But the average monthly electricity consumption for the intake (from the table 4.2) = 1,481,800 kWh

Therefore average monthly energy consumption at the intake for Colombo city area = 618,045 kWh

The average monthly energy consumption of Maligakanda and Ellie House pumps = 1,440,000 kWh

Therefore total monthly average energy consumption for pumping water to Greater Colombo Region (Maligakanda, Ellie house and Intake pumps) = 2,058,045 kWh

4.3 Analysis of NRW in Greater Colombo Region

Based on the findings of the Japanese International Cooperation Agency (JICA) report, a water balance based on readily available data was carried out for Colombo city as a whole, which shows that in terms of the System Input Volume (SIV), 51% was attributed to Revenue water, 33% to real losses, 11% to unbilled authorized consumption from standpipes and 5% to commercial losses Figure 4.1 presents the Colombo city water balance and Figure 4.2 illustrates the Colombo city water balance in bar chart format. Therefore the NRW in Colombo city area is 49% of the total supply.

The real losses (physical losses) are considered as the losses due to leakages from the pipe lines and losses due to overflown of reservoirs. The unbilled authorized consumption is considered as the unbilled unmetered consumption. This is mainly due to the standpipes which are located in Colombo city limits to serve the people who have poor income levels. The commercial losses means illegal connections, customer meter errors and data handling errors. Out of these losses, the highest contributor is the real losses (physical losses) which accounts to 33%.That means the 33% of the pumped quantity is wasted.

According to the International Water Association (IWA) and the standard norms, the total NRW of a developing country should be around 15% [14].Therefore the unavoidable physical losses should come around 7%.Therefore in Colombo city limits, this physical losses component is 26% higher than the standard value. This means 26% of the energy usage for pumping water to Colombo city limits is wasted.

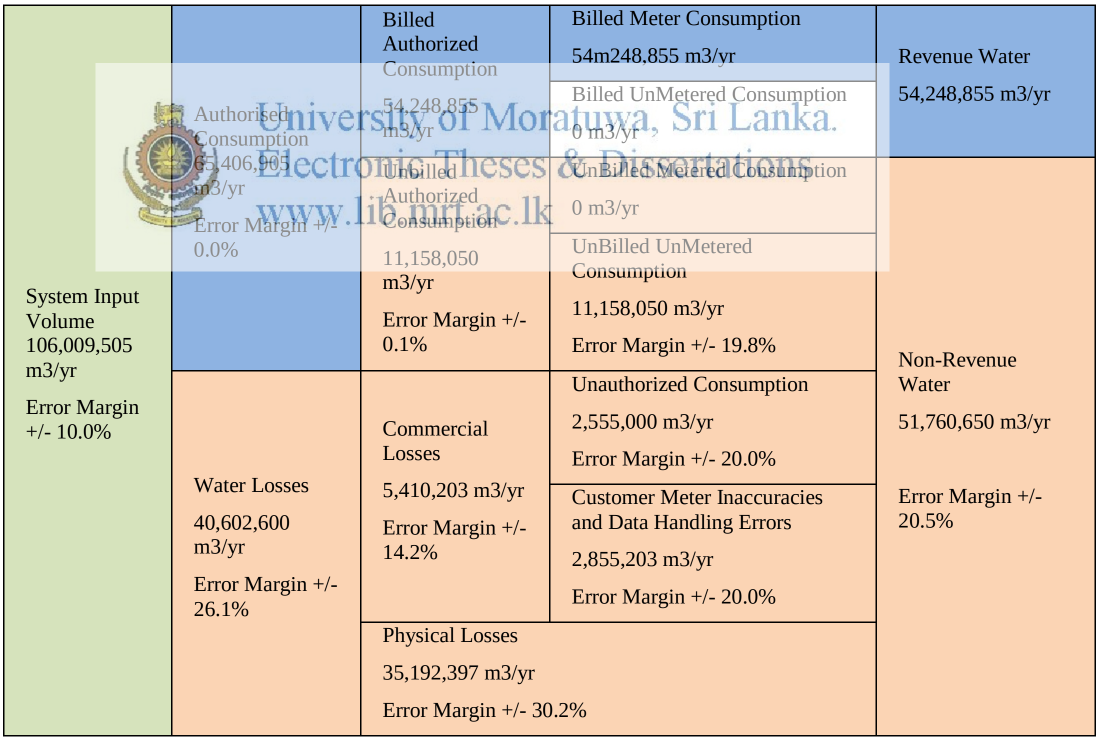


Figure 4.1 Water balance for Colombo District

Source: Japanese International Cooperation Agency Report 2012

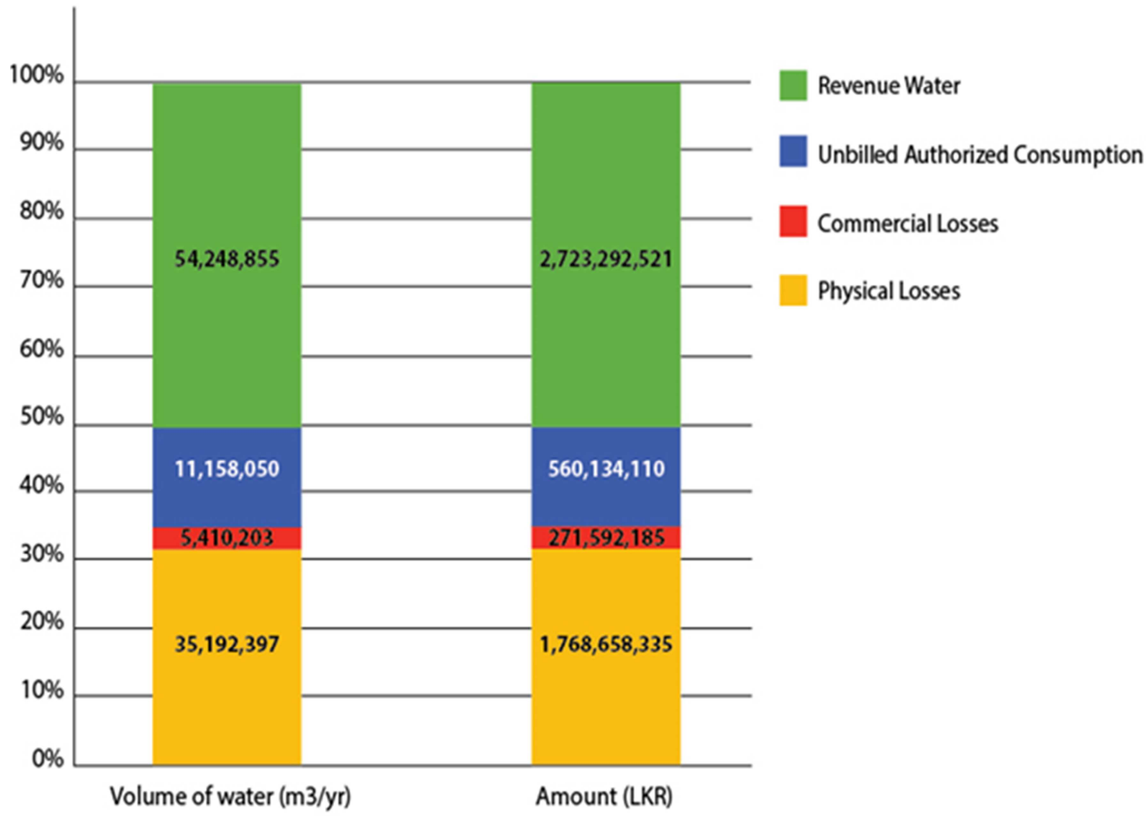


Figure 4.2 Chart of Colombo City Water balance and Value Cost
Source: Japanese International Cooperation Agency (JICA) report 2012

As it was calculated earlier,

Total energy usage per month for pumping to greater Colombo region from Ambatale Treatment Plant	=	2,058,045 kWh
Percentage of loss of water due to physical losses	=	33%
But unavoidable losses due to physical losses according to standards	=	7%
Therefore the wastage that can be avoided	=	26%
Therefore energy wastage	=	0.26 * 2,058,045
Total power wastage due to NRW avoidable physical losses	=	535,092 kWh

Therefore annual energy wastage due to NRW physical losses	**=**	**535,092 x 12**
	=	**6,421,104 kWh**
	=	**6.42 GWhr**
Therefore Annual Cost due to wastage of Energy	=	6,421,104 x 13.60
	=	Rs 87.32 Million

Therefore by applying measures to reduce physical losses in the distribution and transmission systems, this huge amount of wasted energy can be saved.

5 CONCLUSION & RECOMMENDATION

5.1 Introduction

This chapter winds up the research with the recommendations need to reduce and prevent the physical water losses in the distribution and transmission systems thereby saving energy as the objective of this study. It highlights the conclusion and implication of this research and contains some recommendations which could be in the interest of the NWSDB, the supplier of water in Sri Lanka. Finally this chapter gives the limitations of the research and makes suggestions for future research.

5.2 Summary of Findings

This section is dedicated to summaries the findings of the study against the objectives stated in Chapter 1.

Energy consumption at Ambatale WTP

Data was collected with regard energy consumption at Ambatale water treatment plant. This included the average monthly energy consumption for whole plant, average monthly energy consumption of intake, average monthly energy consumption of pumps which are dedicated to greater Colombo water supply, specific energy of the treatment plant.

Water production at Ambatale WTP

The production data of Ambatale WTP was collected. This included the total monthly average water production at Ambatale water treatment plant, monthly average water quantity pumped to greater Colombo region.

NRW Figures in greater Colombo region

This included the data collection on total NRW in identified area, physical losses, unbilled authorized consumption, commercial losses and the reasons for these losses.

5.3 Conclusion

The study is carried out in greater Colombo region of Colombo district and the outcome shows that a very high percentage of energy is wasted by having high physical losses due to pipe line leakages and over flow of reservoirs. Based on these findings, the study focuses on how much energy can be saved by minimizing the physical losses component in total NRW.

The study justifies that the energy saving capacity is very high with the figures shown in the chapter of analysis of data. In addition to that proposed energy saving by reduction of NRW would provide indirect advantage to sustainability of the NWSDB. Therefore, the proposed energy saving by reduction of physical losses of NRW is feasible for the implementation with the subject to recommendations given in the section 5.4.

5.4 Recommendations

- The present higher level of NRW in Colombo city limits occurs due to various reasons. Mainly it shows that the distribution and some of the transmission pipe lines are almost one hundred years old which were laid in British's regime. Therefore the internal leaks are unaccountable. According to Figure 4.1 and 4.2 in chapter 4 it implicates how much water quantity is wasted through internal leaks that are undetected. As such it is highly recommended to replace these old aged pipes with poly ethylene pipes which are manufactured with latest technology.
- Some reasons for high physical losses due to delayed reaction time for the leak repairs. The reason for this goes beyond the NWSDB authority as Colombo city high security zone. A more unified approach to problem solving in the greater Colombo area, where the necessary approvals from security departments are granted in a timely manner. This will reduce wastage of water due to bureaucracy involved in getting permission for repairs.
- The NWSDB should introduce latest technology to the operations system. Mainly new software for digital mapping of the transmission systems and distribution systems, high quality and accurate measuring devises, GIS application, etc, will definitely help to reduce NRW thereby reducing of energy cost.
- Adapting pumping of water to diurnal changes (i.e. line pressure changes during day and night), and also demand variation (during dry season) through variable speed drives (VSD's) will improve efficiency of pumping, and reduce NRW.

- The reservoirs tend to overflow during the low demand times of the day. This issue can be solved by installing Variable Speed Drives (VSD) for starter panels of high lift pumps at Ambatale water treatment plant replacing the soft starters used at present.
- All personnel assigned to pipe installation and leakage repairs should be required to attend formal re-training classes and to demonstrate their capability to correctly install pipes and repair leaks before they are certified as qualified fitters/technicians who are approved to work on the NWSDB asset networks.
- Adequate tools, spares and vehicles need to be provided to enable the staff to carry the work out in a timely manner.
- The system for reporting and repairing leaks needs to be improved. The Call Centre computer system, although an improvement to previous working practices, needs further development. Information pertaining to leak turnaround times, locations of repeat bursts and other important asset management information could be extracted and performance tracked for each OIC zone.
- Integration of the system with the GIS database could provide a valuable tool in asset management of the network and NRW reduction. It is also recommended that the Call Centre operation be expanded. By expanding the operation, extending the team and improving the Call Centre computer system, it should be possible to streamline the customer complaint process, and possibly assist in NRW reduction. Under the present system the OIC's handle the customer complaint after the initial call to the Call Centre. This puts a big strain on the OIC's workload. A system where the Call Centre deal with all aspects of the complaint, getting updates from the OIC when work is complete, would free up the OIC's to continue with their other duties. This expanded and improved Call Centre should be integrated with the NRW Monitoring Centre. The integration of the GIS section with these two would also make sense, enabling a control centre to be setup where all aspects of ongoing operation and maintenance issues could be managed. It makes good practise that the Call Centre, NRW Management Centre and the GIS section should be in close proximity, enabling the easy passing of information between the three groups.

- Lastly but most importantly NWSDB needs to establish an independent special task force to achieve the target of reducing NRW. This team should be equipped with modern equipment and be dedicated to the task. The mandate should authorize this team to carry out solutions, irrespective of where the problem area belongs.

5.5 Future Work

One very important area of research is studying of behavior of pump characteristics with NRW variations. This opens up another way of thinking to saving energy.

Also it is interesting to study how the pump efficiency and the performance changes with the NRW changes in the system. I.e. NRW results in pumps not being run at the best efficiency point, thereby causing reduction in efficiency.

The present research is related to NRW in greater Colombo region and how the energy can be saved with reduction of NRW. The other populated urban areas too contributing to high NRW thereby high energy losses. In these areas the NRW scenario is different and it is interesting for further research in this field.

The main reservoirs and the service reservoirs (overhead towers) in the Colombo city limits are overflown during the day at low demand times. This happens due to various reasons. Some of the reasons are, malfunctioning of water level controllers, negligence of pump operators, human errors, etc. This issue can be solved by using Variable Speed Drives (VSD) so that the pumping capacity is varied according to the demand variation. Therefore this research area can be further extended for analyzing the water loss due to overflow of reservoirs and the cost benefit analysis with the cost incurred in hardware and savings of manpower due to automation of pumping arrangement ultimately the energy saving potential.

There is another way of analyzing the energy usage with the aging of transmission and distribution piping network. It is possible to calculate the pipe friction with the scaling of inner wall of the pipes due to aging and the changes of Reynolds number. These results of calculations and the existing physical data can be used for the research.

Reference List

[1] ADB.(2010).Issues and Challenges of Reducing Non-Revenue Water. Asian Development Bank.

[2] Baumann, D. J., “Urban Water Demand Management and Planning” New York: McGraw-Hill, 1998

[3] Blaxter, L. H., “How to research”, Open University Press: .Milton Keynes, UK, 2006

[4] Boland, J.J., Whittington, D. & Foster, V, “Water Tariff & Subsidies in South Asia”, Washington: PPIAF, Water and Sanitation Program, 2002

[5] Braadbaart, O., "Piped Water services in developing countries: why we know so little about utility performance determinants and where to go from here.". Paper presented at the UNESCO-WOTRO International Working Conference Water for Society. Delft: Institute for infrastructure, Hydraulic and Environmental Engineering, 2000

[6] Joskow, P, Regulation of natural monopolies, Center for Energy and Envoiremental Policy Research. 05-008 WP, 2005

[7] Katko, T., The Role of Cost Recovery in Water Supply in Developing Counties. Tempere, Finland: Tempere University of Technology, 1989

[8] Leak Location and Repair, Guidance Notes, IWA March 2007

[9] Millenium Development Goals. United Nations, 2005

[10] NWSDB. (2007). Coporate Plan 2007-2011.National Water Supply & Drainage Board.

[11] NWSDB National Policy on Drinking Water, 2009

[12] UN. World Water Conference. Mar del Plata, Argentina: United Nations, 1977

[13] Yin, R., Case Study Research: Design and Method, Third Edition. Thousand Oaks, California: Saga Publications, 1994

[14] International Water Association: Assessing NRW and its components - a practical approach, August 2003, accessed on November 29, 2009

[15] Operations and System Control Study for the Greater Colombo Water Supply Systems, 1987-1988

[16] NWSDB Master Plan Update, 1991

[17] Kalu Ganga Feasibility Study, JICA, 1994

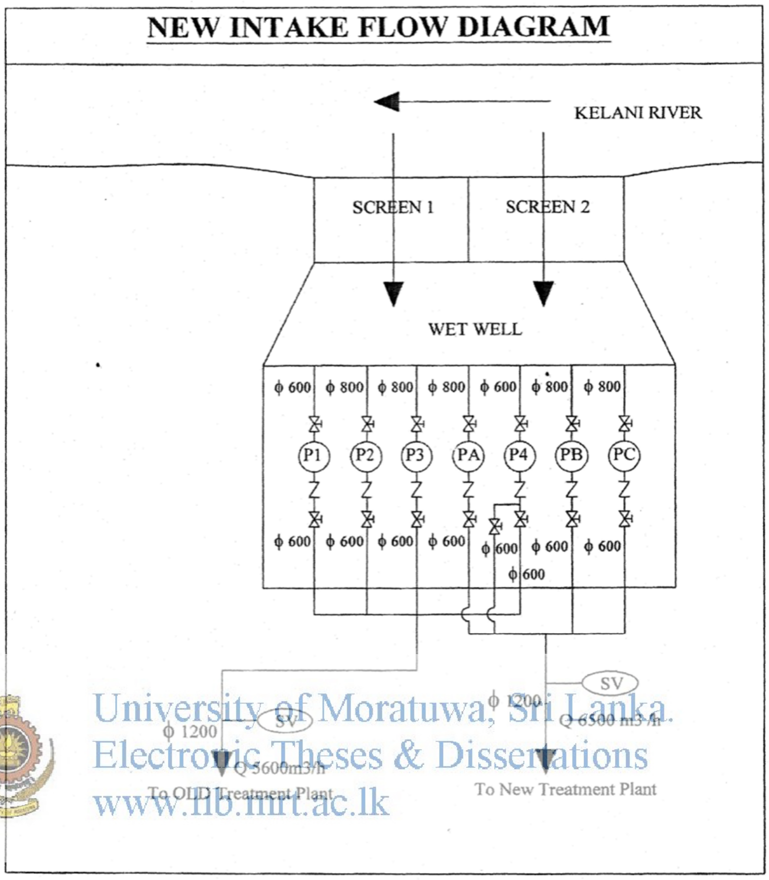
[18] Sri Lanka Third Water Supply & Sanitation Project, 2000

[19] Detailed Design Study on Project for Reduction of NRW in the Greater Colombo Area, 2001

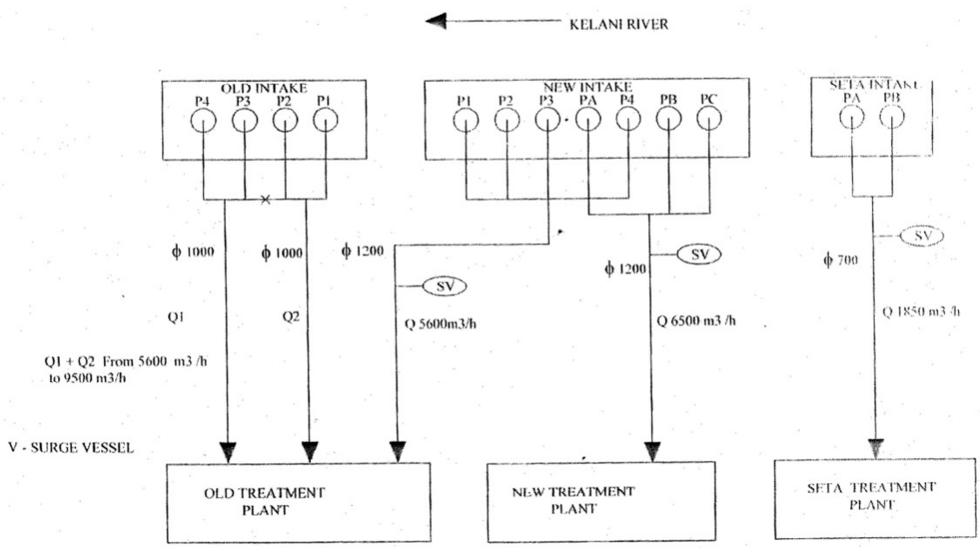
[20] SPROF Study, 2007

[21] Japanese Technical Cooperation for the Capacity Development Project for NRW Reduction in Colombo City, 2009

Appendix A: New Intake Flow

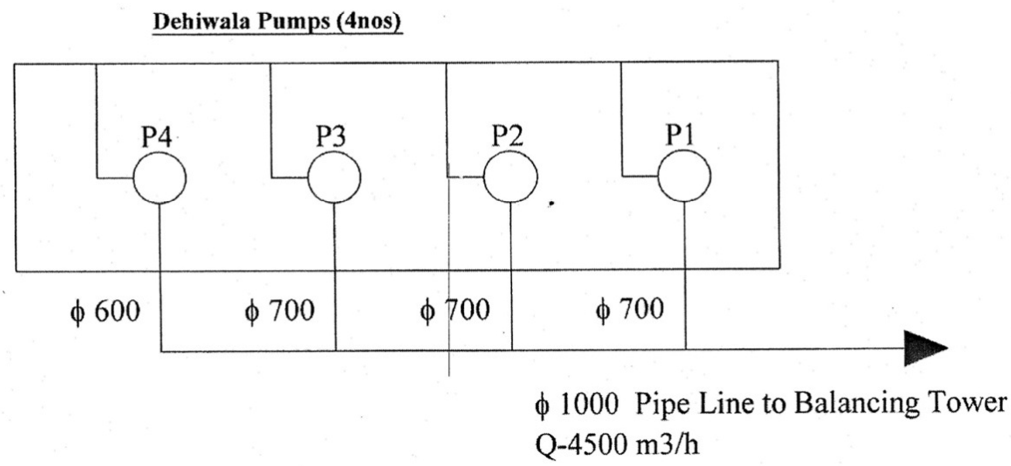


GENERAL FLOW DIAGRAM FOR AMBATALA INTAKE

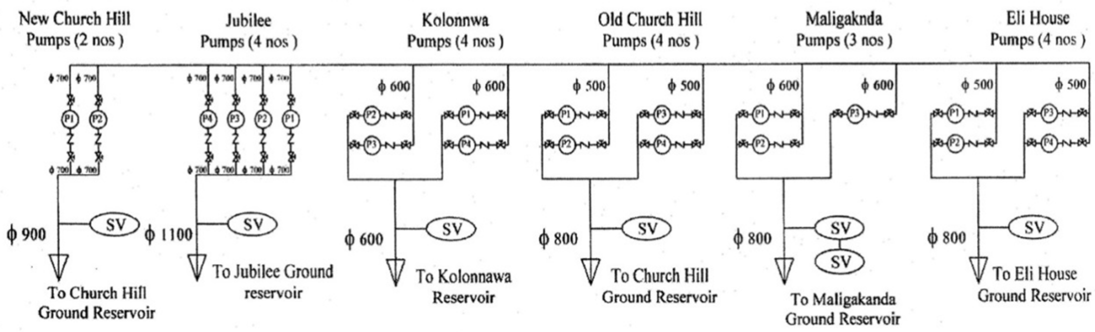


Appendix B: High lift Pumps

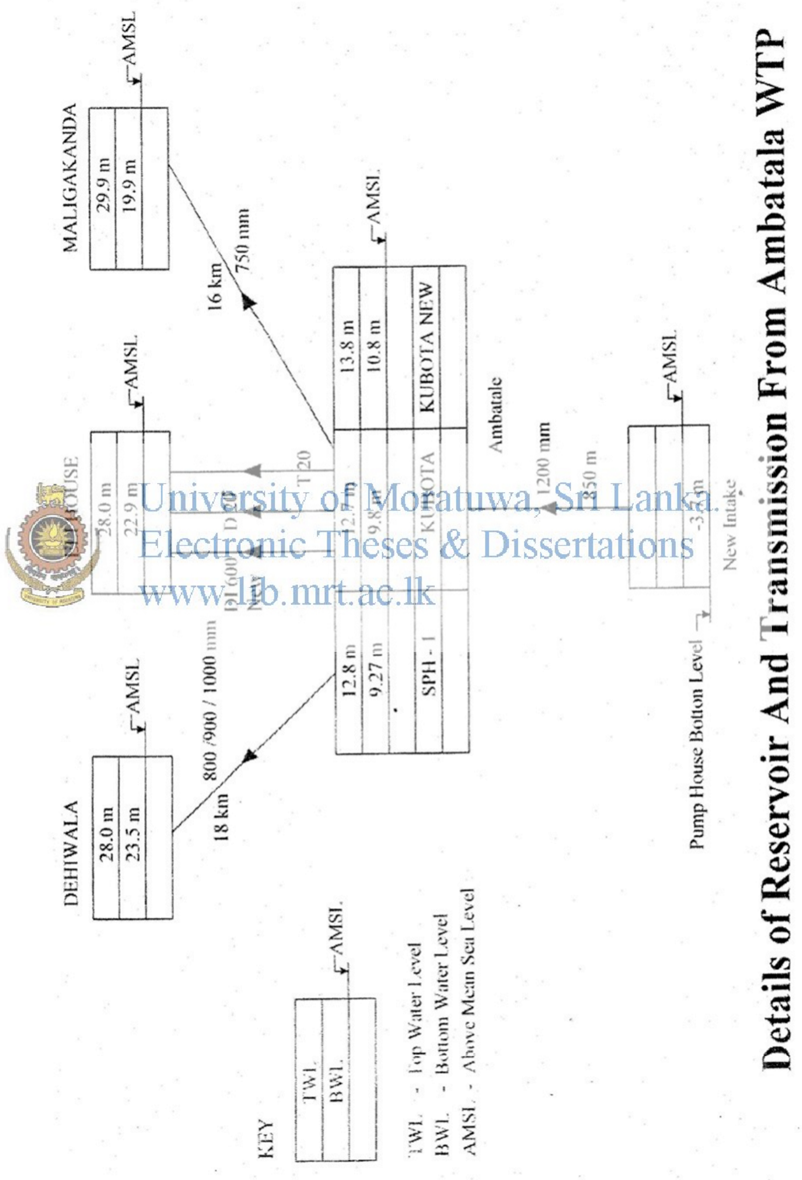
SECONDARY PUMP HOUSE 1



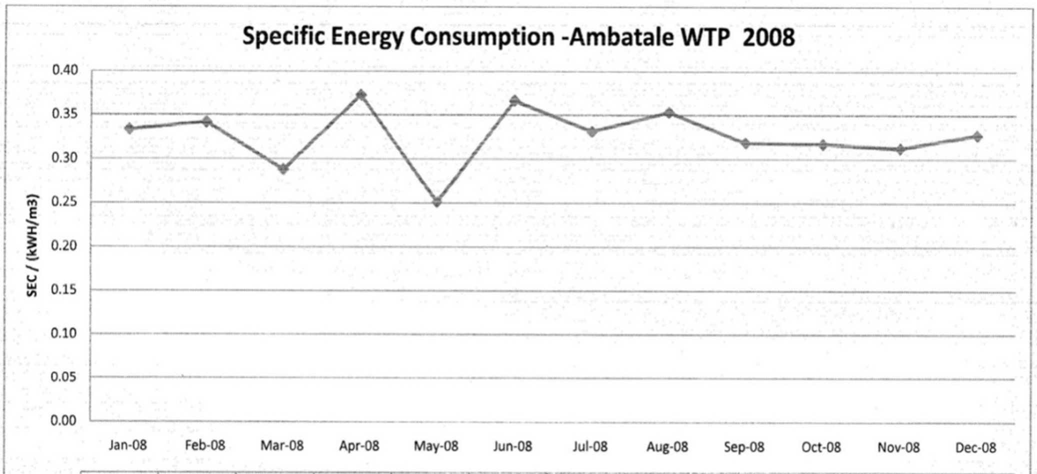
SECONDARY PUMP HOUSE - 2



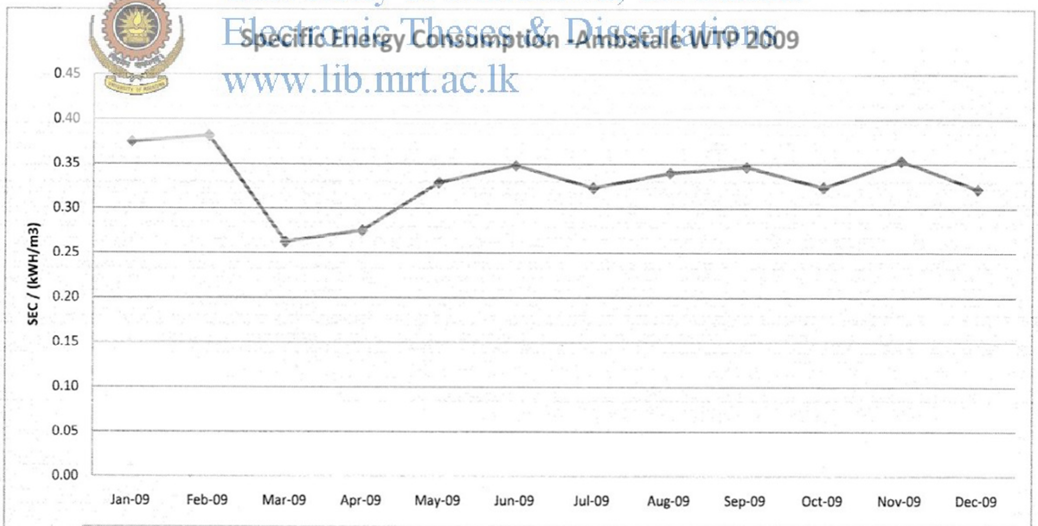
Appendix C: Details of Reservoir and Transmission from Ambathale WTP



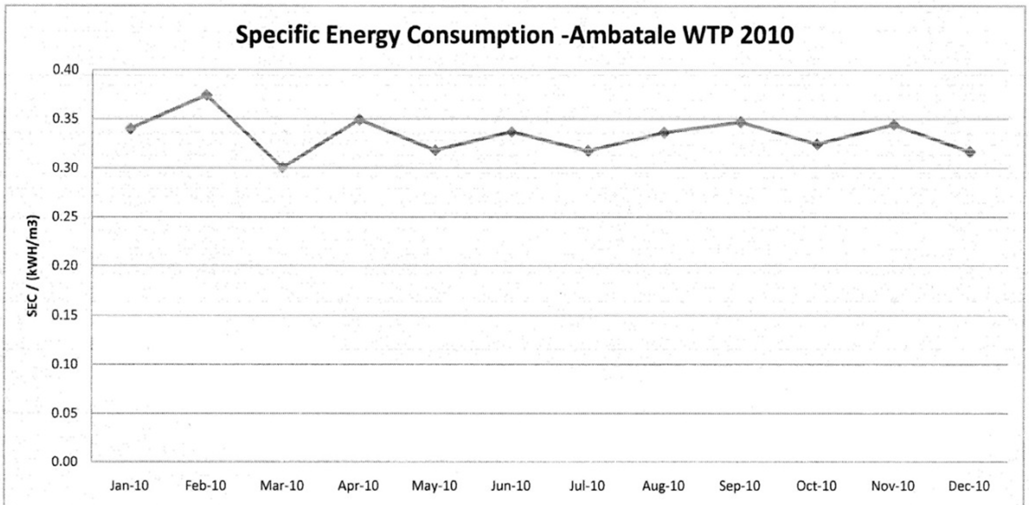
Appendix D: Specific Energy – Ambathale WTP from 2008 - 2012



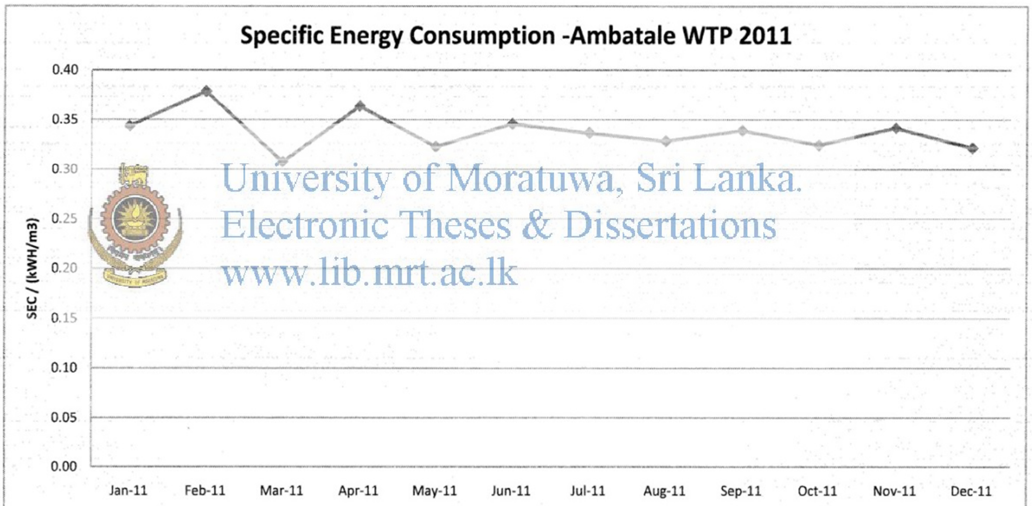
	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08
SEC	0.33	0.34	0.29	0.37	0.25	0.37	0.33	0.35	0.32	0.32	0.31	0.33



	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09
SEC	0.37	0.38	0.26	0.28	0.33	0.35	0.32	0.34	0.35	0.32	0.35	0.32



	Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10
SEC	0.34	0.37	0.30	0.35	0.32	0.34	0.32	0.34	0.35	0.32	0.34	0.32



	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11
SEC	0.34	0.38	0.31	0.36	0.32	0.35	0.34	0.33	0.34	0.32	0.34	0.32

Appendix E: Monthly Pumping Statistics

MONTHLY PUMPING REPORT - AMBATALE
MONTH OF APRIL - 2013

Date	Jubilee	Dehiwala	Elli House	Elli House(N)	Maligakand	CH (Old)	CH (New)	Kalani (CH)	Kolonnawa
	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day
1-Apr-2013	131,228	113,438	73,800	32,799	95,900	-	-	144,500	37,932
2-Apr-2013	131,228	114,597	73,400	33,651	92,100	-	-	146,410	38,979
3-Apr-2013	133,169	113,596	77,300	32,745	94,000	-	-	151,110	39,970
4-Apr-2013	129,329	113,068	75,900	33,145	92,500	-	-	143,079	39,124
5-Apr-2013	132,627	115,865	77,300	33,266	93,500	-	-	154,336	39,840
6-Apr-2013	130,415	116,003	75,800	32,988	92,500	-	-	152,925	39,002
7-Apr-2013	133,710	116,600	77,300	33,806	94,500	-	-	153,430	40,125
8-Apr-2013	133,958	114,213	77,400	32,871	94,500	-	-	143,091	39,980
9-Apr-2013	135,965	107,728	75,400	33,229	92,100	-	-	153,109	38,733
10-Apr-2013	133,955	66,287	77,400	32,871	94,500	-	-	139,132	39,980
11-Apr-2013	147,856	56,750	76,300	33,200	92,700	-	-	134,090	39,355
12-Apr-2013	140,564	116,465	76,000	33,200	92,100	-	-	130,102	39,192
13-Apr-2013	144,527	111,406	76,500	33,133	92,500	-	-	133,166	39,376
14-Apr-2013	127,782	108,227	71,700	33,331	77,000	-	-	120,720	39,211
15-Apr-2013	125,063	100,536	68,200	32,854	73,900	-	-	113,880	39,166
16-Apr-2013	125,038	108,381	69,000	33,476	88,900	-	-	124,462	38,779
17-Apr-2013	126,854	112,324	76,500	33,042	87,000	-	-	132,540	39,384
18-Apr-2013	129,452	112,324	76,600	33,158	85,900	-	-	141,181	39,535
19-Apr-2013	129,841	112,324	76,400	32,951	92,500	-	-	143,105	39,385
20-Apr-2013	130,800	115,891	76,600	33,243	92,400	-	-	137,518	39,638
21-Apr-2013	130,185	112,285	75,300	33,223	92,200	-	-	148,641	38,561
22-Apr-2013	140,837	114,098	76,800	33,139	93,900	-	-	144,771	39,451
23-Apr-2013	140,625	116,309	76,700	32,271	93,400	-	-	143,421	39,669
24-Apr-2013	134,978	116,232	76,200	34,070	92,300	-	-	145,065	39,080
25-Apr-2013	143,645	116,204	76,900	33,853	94,000	-	-	145,860	39,692
26-Apr-2013	136,586	114,634	75,900	32,609	91,900	-	-	145,065	38,642
27-Apr-2013	140,520	115,190	76,500	32,977	93,600	-	-	145,034	39,374
28-Apr-2013	141,932	114,904	77,100	32,784	93,900	-	-	143,545	38,599
29-Apr-2013	142,586	116,365	76,300	32,871	93,300	-	-	149,609	39,648
30-Apr-2013	138,987	113,613	75,800	32,127	92,600	-	-	145,085	39,007
AVG	134,808	109,862	75,610	33,096	91,403			141,599	39,280

MONTHLY PUMPING REPORT - AMBATALE
MONTH OF MARCH - 2013

Date	Jubilee	Dehiwala	Elli House	Elli House(N)	Maligakand	CH (Old)	CH (New)	Kalani (CH)	Kolonnawa
	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day
1-Mar-2013	128,554	116,578	74,900	32,637	91,600	-	-	144,925	39,776
2-Mar-2013	128,916	116,837	74,600	33,463	92,500	-	-	146,010	39,616
3-Mar-2013	131,395	114,327	75,200	33,228	93,400	-	-	140,972	39,144
4-Mar-2013	126,656	108,783	75,000	32,257	92,800	-	-	139,634	40,260
5-Mar-2013	129,616	110,008	74,100	33,378	91,740	-	-	146,550	32,820
6-Mar-2013	129,458	113,913	75,900	32,289	93,900	-	-	140,019	40,301
7-Mar-2013	127,906	115,876	67,700	33,233	92,400	-	-	143,953	39,572
8-Mar-2013	126,822	108,783	75,500	31,962	92,000	-	-	144,083	39,491
9-Mar-2013	124,659	115,000	73,400	33,096	89,600	-	-	141,720	38,305
10-Mar-2013	132,724	115,000	75,800	32,739	93,700	-	-	142,150	39,638
11-Jan-2013	133,030	115,000	75,800	32,839	92,400	-	-	148,958	39,758
12-Jan-2013	132,000	115,000	48,500	22,679	92,300	-	-	143,217	39,466
13-Jan-2013	130,522	115,500	45,100	28,961	93,300	-	-	148,618	39,257
14-Jan-2013	129,978	115,500	74,000	33,239	92,800	-	-	147,590	39,637
15-Jan-2013	127,812	113,650	73,960	32,269	92,400	-	-	140,325	39,296
16-Jan-2013	127,034	116,400	48,700	20,074	93,900	-	-	138,268	39,916
17-Jan-2013	130,654	115,090	74,300	35,395	92,300	-	-	137,714	38,976
18-Jan-2013	127,646	116,764	81,300	32,934	91,900	-	-	144,014	38,960
19-Jan-2013	131,114	113,859	75,100	33,123	92,900	-	-	148,783	39,822
20-Jan-2013	130,020	115,197	73,900	32,095	92,000	-	-	145,299	39,037
21-Jan-2013	131,546	114,500	74,800	33,059	93,200	-	-	145,299	39,539
22-Jan-2013	133,464	114,457	75,800	33,269	92,500	-	-	145,749	39,582
23-Jan-2013	128,710	113,415	75,300	32,930	91,900	-	-	146,217	38,641
24-Jan-2013	129,184	114,355	76,100	33,126	92,500	-	-	142,320	39,456
25-Jan-2013	129,027	110,051	75,300	33,542	91,200	-	-	134,840	38,504
26-Jan-2013	110,836	110,886	77,300	33,419	93,800	-	-	147,012	39,698
27-Jan-2013	127,134	113,115	74,200	32,395	90,000	-	-	137,917	38,344
28-Jan-2013	132,125	114,269	76,900	33,571	93,100	-	-	142,220	39,697
29-Jan-2013	115,081	108,469	67,000	28,954	81,600	-	-	143,665	34,713
30-Jan-2013	129,705	114,805	76,400	33,370	93,300	-	-	150,006	39,411
31-Jan-2013	133,286	113,301	78,800	33,257	89,900	-	-	146,844	35,835
AVG	128,600	113,829	72,279	32,025	92,027	-	-	143,706	38,918

MONTHLY PUMPING REPORT - AMBATALE
MONTH OF FEBRUARY 2013

Date	Jubilee	Dehiwala	Elli House	Elli House(N)	Maligakand	CH (Old)	CH (New)	Kalani (CH)	Kolonnawa
	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day
21/1/2013	130,604	117,386	75,500	32,548	94,200	-	-	131,340	39,635
2-Feb-2013	126,665	116,114	73,500	32,934	91,800	-	-	145,690	38,464
3-Feb-2013	130,786	113,412	73,800	33,078	92,600	-	-	149,995	38,848
4-Feb-2013	129,602	115,011	74,600	32,797	93,200	-	-	135,260	39,376
5-Feb-2013	130,375	114,083	74,500	33,143	92,700	-	-	140,799	39,198
6-Feb-2013	124,109	114,083	73,400	32,044	92,700	-	-	142,263	38,606
7-Feb-2013	126,078	114,000	75,500	33,198	91,000	-	-	143,788	39,434
8-Feb-2013	126,206	117,270	75,300	32,896	91,300	-	-	139,750	39,153
9-Feb-2013	125,901	112,797	74,900	32,476	91,400	-	-	136,331	38,896
10-Feb-2013	126,595	114,950	74,200	33,208	91,600	-	-	128,267	38,653
11-Feb-2013	125,242	98,431	74,500	32,009	82,100	-	-	134,855	38,681
12-Feb-2013	127,034	92,609	74,600	33,621	91,400	-	-	132,329	39,111
13-Feb-2013	124,383	99,228	75,100	32,441	87,500	-	-	133,827	38,931
14-Feb-2013	126,651	114,459	74,800	32,999	91,800	-	-	138,346	39,491
15-Feb-2013	124,474	114,779	74,600	32,899	83,600	-	-	132,700	38,531
16-Feb-2013	128,142	115,299	75,100	32,990	92,500	-	-	144,179	39,231
17-Feb-2013	130,871	115,463	75,200	32,834	93,000	-	-	143,079	39,130
18-Feb-2013	128,949	114,049	74,700	33,108	84,700	-	-	145,717	35,655
19-Feb-2013	125,627	116,335	74,900	33,447	92,600	-	-	145,717	28,389
20-Feb-2013	127,830	114,289	74,700	32,438	91,800	-	-	144,519	39,345
21-Feb-2013	129,836	113,986	74,800	33,124	92,500	-	-	146,408	39,675
22-Feb-2013	133,854	115,483	77,600	33,053	86,500	-	-	140,122	40,948
23-Feb-2013	123,501	114,031	72,200	32,934	89,200	-	-	141,954	38,031
24-Feb-2013	129,845	115,662	75,200	33,129	92,900	-	-	139,694	39,995
25-Feb-2013	132,362	113,625	75,600	32,999	94,000	-	-	139,663	40,222
26-Feb-2013	129,582	114,112	73,900	33,478	91,000	-	-	139,513	39,255
27-Feb-2013	130,383	109,926	71,600	32,681	92,500	-	-	152,335	39,506
28-Feb-2013	131,678	110,223	74,900	33,364	92,400	-	-	149,730	39,710
AVG	128,113	112,540	74,614	32,924	90,875	-	-	140,649	38,718

MONTHLY PUMPING REPORT - AMBATALE
MONTH OF JANUARY 2013

Date	Jubilee	Dehiwala	Elli House	Elli House(N)	Maligakand	CH (Old)	CH (New)	KRB (CH)	Kolonnawa
	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day
1-Jan-2013	125,445	113,317	72,200	32,654	87,300	-	-	134,367	33,835
2-Jan-2013	125,670	115,632	73,700	31,893	89,400	25,200	-	127,761	34,013
3-Jan-2013	124,622	115,108	73,100	33,494	87,600	24,700	-	131,180	31,530
4-Jan-2013	121,556	115,229	73,300	32,202	88,100	24,900	-	127,720	29,168
5-Jan-2013	125,286	112,992	71,500	32,630	83,500	11,500	-	144,472	30,343
6-Jan-2013	129,048	113,078	73,600	32,715	80,900	-	-	153,358	31,659
7-Jan-2013	123,444	115,646	69,100	32,379	80,500	-	-	159,882	30,168
8-Jan-2013	127,616	112,869	73,100	32,757	84,100	-	-	159,401	38,145
9-Jan-2013	127,309	112,869	73,800	32,209	80,600	-	-	154,622	38,651
10-Jan-2013	118,572	112,095	73,500	33,123	72,300	-	-	146,526	38,585
11-Jan-2013	127,960	112,004	74,600	32,674	80,400	-	-	154,092	39,401
12-Jan-2013	123,806	112,004	72,800	33,103	74,900	-	-	162,398	37,990
13-Jan-2013	122,130	111,801	73,800	32,555	83,800	-	-	152,594	39,056
14-Jan-2013	127,958	110,548	69,000	32,492	71,400	-	-	152,926	38,860
15-Jan-2013	132,423	112,717	72,400	33,033	78,800	-	-	157,833	38,776
16-Jan-2013	127,836	112,982	71,100	32,069	84,000	-	-	161,465	38,005
17-Jan-2013	129,217	111,777	73,600	32,811	80,700	-	-	159,186	39,121
18-Jan-2013	122,130	113,843	74,200	32,324	82,100	-	-	159,549	38,682
19-Jan-2013	100,245	76,371	47,700	23,997	67,400	-	-	156,400	26,042
20-Jan-2013	133,309	113,877	71,600	32,661	89,000	-	-	161,541	38,890
21-Jan-2013	133,300	117,254	73,700	32,670	88,400	18,300	-	141,238	38,797
22-Jan-2013	128,602	113,361	73,100	33,141	89,000	21,600	-	138,782	38,728
23-Jan-2013	133,300	115,716	72,300	32,404	84,700	18,300	-	130,048	38,762
24-Jan-2013	126,672	114,321	73,300	31,622	91,100	-	-	136,140	39,448
25-Jan-2013	124,688	114,678	70,500	34,213	90,000	-	-	140,922	38,855
26-Jan-2013	127,570	113,688	70,400	32,885	90,700	-	-	138,875	39,021
27-Jan-2013	126,400	106,431	69,300	32,503	88,600	18,287	-	137,067	39,134
28-Jan-2013	133,300	109,988	61,700	32,500	76,800	21,700	-	142,143	39,044
29-Jan-2013	129,697	114,921	62,500	33,331	82,700	14,100	-	144,682	39,114
30-Jan-2013	128,431	116,473	74,100	32,015	92,300	2,600	-	142,651	36,733
31-Jan-2013	130,012	114,751	74,600	32,955	93,100	-	-	143,180	39,374
AVG	126,373	112,211	71,071	32,388	83,684	6,490		146,871	36,707

MONTHLY PUMPING REPORT - AMBATALE
MONTH OF DECEMBER 2012

Date	Jubilee	Dehiwala	Elli House	Elli House(N)	Maligakand	CH (Old)	CH (New)	KRB (CH)	Kolonnawa
	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day
1-Dec-2012	126,271	113,831	59,100	32,798	89,000	-	-	160,306	34,963
2-Dec-2012	129,580	108,357	80,700	32,735	80,500	-	-	158,375	35,341
3-Dec-2012	126,273	113,818	59,091	32,818	89,000	-	-	158,375	34,955
4-Dec-2012	126,496	112,910	73,000	32,570	88,600	-	-	149,025	28,817
5-Dec-2012	124,415	113,860	72,500	32,510	87,700	-	-	163,957	34,062
6-Dec-2012	128,015	114,748	75,100	32,510	90,800	-	-	158,433	36,448
7-Dec-2012	128,433	112,875	74,200	32,658	89,000	-	-	154,117	34,960
8-Dec-2012	125,351	116,108	71,700	32,961	69,200	-	-	157,639	35,126
9-Dec-2012	134,426	114,458	75,100	32,961	90,600	-	-	158,628	35,746
10-Dec-2012	133,619	111,359	74,200	32,191	88,100	-	-	151,227	35,416
11-Dec-2012	127,490	115,229	72,700	32,829	89,600	-	-	164,325	30,212
12-Dec-2012	130,321	116,369	74,060	32,566	90,200	-	-	164,336	35,608
13-Dec-2012	128,550	115,300	73,000	31,900	89,500	-	-	161,836	35,999
14-Dec-2012	126,946	115,126	74,100	32,601	89,100	-	-	159,424	35,207
15-Dec-2012	127,330	112,683	72,600	33,081	90,100	-	-	163,951	35,390
16-Dec-2012	127,106	115,468	72,300	32,848	90,400	-	-	150,657	34,827
17-Dec-2012	120,933	114,321	67,300	33,666	89,100	-	-	150,985	31,007
18-Dec-2012	122,034	116,957	68,500	32,222	89,100	-	-	156,048	30,610
19-Dec-2012	124,128	111,481	72,000	32,664	88,800	-	-	150,119	31,388
20-Dec-2012	127,378	112,601	74,300	33,043	90,100	-	-	157,142	33,327
21-Dec-2012	124,861	112,420	73,575	32,714	89,450	-	-	159,966	32,591
22-Dec-2012	122,343	112,238	72,850	32,384	88,800	-	-	154,954	31,854
23-Dec-2012	127,940	113,056	71,500	32,733	90,400	-	-	148,800	33,890
24-Dec-2012	123,134	111,089	72,800	32,982	84,500	-	-	161,754	33,068
25-Dec-2012	122,075	113,663	69,100	32,000	80,700	-	-	148,766	34,075
26-Dec-2012	122,327	112,719	66,700	33,051	86,000	-	-	153,057	33,927
27-Dec-2012	129,168	112,025	73,100	32,438	89,000	-	-	154,271	33,927
28-Dec-2012	124,044	113,557	71,200	32,270	80,000	-	-	154,759	33,838
29-Dec-2012	127,350	113,009	74,300	32,672	89,000	-	-	158,498	34,055
30-Dec-2012	129,168	112,025	73,100	32,438	89,000	-	-	154,400	33,431
31-Dec-2012	132,550	113,559	75,000	32,659	91,200	-	-	146,526	34,857
AVG	126,776	113,265	71,896	32,660	87,631	-	-	156,279	33,836

MONTHLY PUMPING REPORT - AMBATALE
MONTH OF November 2012

Date	Jubilee	Dehiwala	Elli House	Elli House(N)	Maligakand	CH (Old)	CH (New)	KRB (CH)	Kolonnawa
	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day
1-Nov-2012	130,206	106,400	76,100	33,047	91,400	-	-	147,726	35,198
2-Nov-2012	132,500	110,500	75,200	32,400	91,500	-	-	150,100	35,750
3-Nov-2012	131,562	111,862	74,500	32,547	90,000	-	-	166,692	34,873
4-Nov-2012	134,635	112,978	75,300	32,682	90,900	-	-	158,085	35,463
5-Nov-2012	136,026	112,824	77,000	32,386	93,100	-	-	157,041	36,279
6-Nov-2012	129,908	112,075	71,100	33,119	90,000	-	-	156,253	34,894
7-Nov-2012	130,780	113,222	74,900	32,417	90,200	-	-	161,764	35,103
8-Nov-2012	130,500	111,300	73,500	32,200	90,500	77,200	-	83,500	35,400
9-Nov-2012	128,714	106,131	72,700	31,946	87,000	74,200	-	98,447	34,758
10-Nov-2012	126,479	108,000	48,400	33,250	91,500	78,900	-	78,461	34,488
11-Nov-2012	134,303	106,400	69,100	33,281	88,300	71,500	-	98,447	35,667
12-Nov-2012	133,735	106,400	67,100	32,193	93,300	44,500	-	145,500	35,936
13-Nov-2012	128,172	107,450	66,700	28,965	88,600	44,700	-	147,871	34,016
14-Nov-2012	131,992	115,192	65,500	32,248	92,300	-	-	154,203	35,225
15-Nov-2012	131,713	113,587	62,600	33,092	92,300	-	-	155,100	35,430
16-Nov-2012	131,586	111,239	64,800	32,575	92,200	-	-	158,352	32,500
17-Nov-2012	132,513	113,422	63,500	32,715	92,000	-	-	158,447	34,917
18-Nov-2012	133,652	114,488	67,500	32,939	92,800	-	-	161,178	35,323
19-Nov-2012	133,652	114,488	67,500	32,939	92,800	-	-	158,648	35,323
20-Nov-2012	133,668	113,467	66,400	33,778	92,600	-	-	164,558	35,165
21-Nov-2012	134,159	116,677	67,000	32,800	92,200	-	-	159,876	35,349
22-Nov-2012	134,240	110,436	68,100	32,917	93,100	-	-	166,988	35,623
23-Nov-2012	131,625	115,740	70,000	32,535	91,600	-	-	158,625	35,733
24-Nov-2012	127,967	116,900	70,100	32,887	88,200	-	-	169,138	34,575
25-Nov-2012	132,740	116,900	72,300	31,878	92,300	-	-	154,946	33,341
26-Nov-2012	127,374	116,197	68,000	33,374	79,400	-	-	157,357	35,048
27-Nov-2012	127,374	116,197	68,000	33,374	79,400	-	-	157,357	35,048
28-Nov-2012	127,508	112,416	71,700	31,999	88,100	-	-	161,732	34,468
29-Nov-2012	127,966	115,846	75,000	33,088	90,800	-	-	157,100	35,675
30-Nov-2012	128,015	114,748	75,100	32,510	90,800	-	-	158,433	36,448
AVG	131,175	112,449	69,490	32,603	90,307	13,033	-	148,731	35,101

MONTHLY PUMPING REPORT - AMBATALE
MONTH OF OCTOBER 2012

Date	Jubilee	Dehiwala	Elli House	Elli House(N)	Maligakand	CH (Old)	CH (New)	KRB (CH)	Kolonnawa
	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day
1-Oct-2012	134,643	111,459	71,700	32,893	91,200	-	-	178,421	35,536
2-Oct-2012	132,684	109,771	74,200	32,307	89,800	-	-	179,882	35,236
3-Oct-2012	131,001	111,063	72,400	32,957	86,900	-	-	173,490	34,693
4-Oct-2012	135,712	109,192	74,800	31,671	88,800	-	-	180,765	36,037
5-Oct-2012	133,920	114,042	74,700	33,724	89,700	-	-	154,450	34,864
6-Oct-2012	131,762	114,750	73,700	32,671	88,200	27,900	-	174,938	34,731
7-Oct-2012	133,546	137,435	73,800	32,454	88,500	45,200	-	135,121	35,227
8-Oct-2012	134,254	112,176	74,200	32,750	88,900	45,300	-	148,945	35,326
9-Oct-2012	134,254	112,176	74,200	32,750	88,900	45,300	-	148,945	35,326
10-Oct-2012	133,368	114,787	74,400	32,251	89,000	42,300	-	149,935	35,468
11-Oct-2012	133,067	111,502	74,229	32,733	89,075	4,994	-	71,472	34,822
12-Oct-2012	135,292	114,226	75,727	33,142	91,072	-	-	159,558	35,367
13-Oct-2012	127,574	111,548	73,593	32,007	87,985	908	-	173,432	34,186
14-Oct-2012	122,535	111,502	75,228	32,643	92,798	-	-	71,472	31,825
15-Oct-2012	129,556	106,030	72,700	31,238	89,300	-	-	173,125	34,318
16-Oct-2012	129,234	115,505	73,700	33,907	90,600	-	-	149,577	34,040
17-Oct-2012	134,420	113,049	75,600	33,158	91,900	-	-	158,318	35,420
18-Oct-2012	129,637	110,390	74,600	33,518	90,000	-	-	145,647	34,619
19-Oct-2012	134,420	113,430	75,800	32,175	92,000	-	-	153,940	35,282
20-Oct-2012	135,816	109,888	74,200	32,963	88,800	-	-	154,974	35,974
21-Oct-2012	129,035	112,486	72,300	34,012	88,000	-	-	150,688	33,670
22-Oct-2012	129,035	112,486	72,300	34,012	88,000	-	-	150,688	33,670
23-Oct-2012	131,843	106,000	75,800	33,759	91,900	-	-	150,688	35,268
24-Oct-2012	126,414	104,400	71,800	31,793	86,900	-	-	153,414	33,347
25-Oct-2012	134,205	112,000	75,400	32,687	91,500	-	-	157,702	35,279
26-Oct-2012	132,235	114,974	75,000	32,393	90,400	-	-	154,497	34,869
27-Oct-2012	134,819	109,866	76,100	32,842	91,900	-	-	158,166	35,655
28-Oct-2012	134,819	109,866	76,100	32,842	91,900	-	-	136,754	35,655
29-Oct-2012	132,430	110,223	75,400	32,506	90,800	-	-	136,343	35,294
30-Oct-2012	132,430	110,223	75,400	32,506	90,800	-	-	146,805	35,294
31-Oct-2012	127,214	106,369	71,300	32,245	88,800	-	-	145,388	34,198
AVG	131,973	112,026	74,206	32,758	89,817	30,272	-	150,888	34,855

MONTHLY PUMPING REPORT - AMBATALE
MONTH OF SEPTEMBER 2012

Date	Jubilee	Dehiwala	Elli House	Elli House(N)	Maligakand	CH (Old)	CH (New)	KRB (CH)	Kolonnawa
	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day
1-Sep-2012	117,696	106,520	70,600	32,876	86,600	42,000	-	130,503	32,948
2-Sep-2012	130,555	108,233	72,600	32,938	85,500	42,100	-	133,202	35,678
3-Sep-2012	131,930	108,233	70,300	32,260	90,800	39,900	-	133,863	35,672
4-Sep-2012	126,145	105,620	68,200	33,740	87,000	44,300	-	138,237	35,157
5-Sep-2012	130,815	108,615	64,000	32,540	88,400	41,800	-	131,593	34,968
6-Sep-2012	132,278	110,251	74,200	32,375	89,600	36,200	-	144,771	35,509
7-Sep-2012	127,465	107,997	78,300	34,077	88,300	39,400	-	129,901	36,636
8-Sep-2012	132,403	114,649	73,800	33,065	87,600	42,000	-	139,624	34,000
9-Sep-2012	130,491	111,997	74,100	32,364	87,500	44,300	-	137,776	35,503
10-Sep-2012	134,624	115,408	71,300	33,799	90,300	43,800	-	138,054	35,654
11-Sep-2012	131,342	111,900	71,700	32,808	87,100	41,600	-	136,582	34,937
12-Sep-2012	131,342	111,900	71,700	32,808	87,100	41,600	-	136,582	34,937
13-Sep-2012	135,098	112,609	74,800	33,301	89,000	-	-	182,400	35,613
14-Sep-2012	133,534	114,727	74,200	32,958	87,700	-	-	180,973	35,408
15-Sep-2012	131,742	107,543	73,900	33,314	87,700	-	-	172,655	34,849
16-Sep-2012	133,370	114,382	72,500	32,802	89,700	-	-	178,226	35,565
17-Sep-2012	132,556	111,256	68,300	32,910	88,100	-	-	175,738	35,068
18-Sep-2012	135,050	162,357	75,300	33,496	89,900	-	-	178,978	35,654
19-Sep-2012	130,800	114,177	71,000	33,043	86,900	-	-	172,339	34,364
20-Sep-2012	130,480	113,800	72,500	32,500	88,900	-	-	181,603	34,500
21-Sep-2012	133,109	112,865	73,700	33,150	88,000	-	-	179,315	34,972
22-Sep-2012	129,375	106,955	73,600	33,028	87,400	-	-	165,772	34,749
23-Sep-2012	132,494	113,464	70,600	32,831	88,300	-	-	178,042	35,076
24-Sep-2012	131,338	114,093	73,900	33,366	90,600	-	-	165,013	35,957
25-Sep-2012	131,521	112,718	73,200	32,821	87,500	-	-	180,372	34,682
26-Sep-2012	133,479	114,240	74,400	33,259	88,900	-	-	176,672	35,233
27-Sep-2012	133,050	114,455	74,200	32,864	88,800	-	-	169,102	36,128
28-Sep-2012	134,193	114,925	71,400	33,032	88,618	-	-	177,267	35,423
29-Sep-2012	130,582	111,621	74,200	33,067	88,800	-	-	176,655	34,694
30-Sep-2012	134,643	111,459	71,700	32,893	91,200	-	-	178,421	35,536
AVG	131,450	113,299	72,473	33,010	88,394	41,583		160,008	35,169

MONTHLY PUMPING REPORT - AMBATALE
MONTH OF AUGUST 2012

Date	Jubilee	Dehiwala	Elli House	Elli House(N)	Maligakand	CH (Old)	CH (New)	KRB (CH)	Kolonnawa
	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day
1-Aug-2012	132,866	113,854	73,900	32,341	82,100	32,000	-	150,480	36,362
2-Aug-2012	132,866	113,479	74,200	32,756	83,800	45,000	-	145,236	36,404
3-Aug-2012	132,866	115,075	74,000	32,308	81,200	42,600	-	141,100	35,033
4-Aug-2012	132,866	115,420	69,500	32,874	82,800	43,800	-	135,937	35,091
5-Aug-2012	132,866	114,888	76,500	32,519	83,100	43,700	-	150,925	35,443
6-Aug-2012	132,866	109,515	71,600	32,011	80,800	42,600	-	139,342	34,219
7-Aug-2012	132,866	106,754	74,300	32,800	82,000	43,000	-	137,472	28,168
8-Aug-2012	132,866	106,943	75,800	31,727	84,600	43,900	-	141,100	36,210
9-Aug-2012	132,866	115,070	70,800	34,123	80,600	44,400	-	148,940	35,023
10-Aug-2012	132,866	114,218	73,200	32,905	84,500	44,100	-	130,864	35,924
11-Aug-2012	132,866	114,156	68,500	32,796	81,400	42,800	-	131,733	31,338
12-Aug-2012	132,866	115,769	73,600	33,028	83,500	44,000	-	151,854	33,792
13-Aug-2012	132,866	112,166	69,100	32,882	83,000	43,900	-	142,511	35,082
14-Aug-2012	132,866	112,170	71,300	33,364	82,200	38,400	-	133,265	34,995
15-Aug-2012	132,866	112,678	71,200	32,582	85,000	43,000	-	145,902	35,380
16-Aug-2012	132,866	107,253	73,000	33,072	86,800	42,700	-	143,672	35,374
17-Aug-2012	132,866	105,301	69,600	32,009	85,100	41,300	-	134,022	34,290
18-Aug-2012	132,866	111,453	72,700	32,659	86,200	42,300	-	137,117	34,695
19-Aug-1900	132,866	114,941	72,100	33,135	87,100	43,100	-	139,519	35,954
20-Aug-2012	132,866	103,189	71,900	33,293	87,300	42,200	-	136,711	35,268
21-Aug-1900	132,866	110,726	72,300	32,617	86,000	42,500	-	136,965	35,789
22-Aug-1900	132,866	110,508	67,500	32,593	88,600	42,300	-	143,935	35,377
23-Aug-2012	132,866	111,094	73,100	32,974	89,300	42,600	-	135,286	36,156
24-Aug-2012	132,866	112,142	68,400	32,874	86,400	41,700	-	126,356	34,728
25-Aug-2012	132,866	112,291	72,700	32,704	89,400	42,600	-	142,189	35,691
26-Aug-2012	132,866	112,291	72,700	32,704	89,400	42,600	-	142,189	35,691
27-Aug-2012	132,866	111,550	72,150	31,500	88,500	42,500	-	138,500	35,500
28-Aug-2012	132,866	113,478	68,400	33,098	89,700	44,000	-	137,119	35,682
29-Aug-2012	132,866	110,604	69,500	32,708	87,200	42,100	-	135,830	34,944
30-Aug-2012	132,866	104,998	66,700	33,339	87,950	42,200	-	129,614	35,400
31-Aug-2012	132,866	110,251	74,200	32,375	89,600	36,200	-	144,771	35,509
AVG	132,866	111,427	71,756	32,743	85,327	42,261		139,692	34,984

MONTHLY PUMPING REPORT - AMBATALE
MONTH OF JULY 2012

Date	Jubilee	Dehiwala	Elli House	Elli House(N)	Maligakand	CH (Old)	CH (New)	KRB (CH)	Kolonnawa
	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day
1-Jul-2012	132,456	115,016	72,500	32,792	83,000	-	-	133,327	35,443
2-Jul-2012	130,075	113,541	60,800	33,127	83,100	-	-	165,625	35,281
3-Jul-2012	136,007	114,170	57,000	33,064	84,100	-	-	171,850	35,842
4-Jul-2012	132,881	113,788	64,400	32,883	81,100	-	-	174,657	34,409
5-Jul-2012	137,500	115,061	75,600	33,724	83,500	-	-	173,154	35,669
6-Jul-2012	136,450	114,913	69,500	32,250	82,900	28,200	-	119,478	35,283
7-Jul-2012	134,847	114,875	74,000	32,965	82,300	-	-	177,691	34,975
8-Jul-2012	137,128	115,910	51,700	32,844	83,800	-	-	169,133	31,960
9-Jul-2012	129,689	114,438	68,800	32,782	82,400	-	-	143,985	39,052
10-Jul-2012	134,810	112,862	52,400	33,311	82,700	-	-	201,342	35,135
11-Jul-2012	134,451	113,016	71,300	32,714	82,800	-	-	170,162	35,079
12-Jul-2012	134,500	113,100	71,250	32,750	82,500	-	-	178,913	35,120
13-Jul-2012	133,866	113,461	74,300	26,497	80,700	-	-	168,626	34,985
14-Jul-2012	134,851	117,857	62,600	33,130	83,300	-	-	164,430	35,090
15-Jul-2012	135,158	115,970	75,500	33,223	83,100	-	-	171,592	35,642
16-Jul-2012	138,438	116,030	63,600	21,023	83,100	-	-	172,256	35,373
17-Jul-2012	137,166	116,556	72,000	32,268	80,100	-	-	174,360	35,674
18-Jul-2012	133,628	116,712	68,300	32,702	81,600	-	-	167,606	34,773
19-Jul-1900	138,639	111,564	76,200	31,707	84,400	-	-	174,175	36,487
20-Jul-2012	137,492	121,731	74,300	34,091	82,300	-	-	172,949	34,942
21-Jul-1900	135,489	116,277	69,500	33,074	82,200	-	-	177,207	34,951
22-Jul-1900	136,978	114,785	75,600	32,835	82,300	-	-	175,221	35,563
23-Jul-2012	138,456	114,947	75,000	32,913	83,700	-	-	175,637	35,216
24-Jul-2012	137,318	112,067	75,400	33,270	83,200	-	-	172,153	35,148
25-Jul-2012	132,308	111,019	72,200	32,514	80,300	-	-	172,722	33,836
26-Jul-2012	131,850	112,085	75,500	33,203	83,000	-	-	172,993	35,545
27-Jul-2012	137,414	115,922	75,200	32,617	80,400	35,900	18	92,043	35,143
28-Jul-2012	131,130	113,719	75,100	32,716	82,600	-	-	174,934	35,093
29-Jul-2012	133,404	114,542	74,200	32,767	83,400	-	-	186,774	35,795
30-Jul-2012	135,278	115,742	73,600	32,540	82,900	-	-	172,009	35,401
31-Jul-2012	134,810	113,911	70,300	32,960	82,900	32,000	-	166,611	36,171
AVG	134,983	111,471	69,924	32,299	82,571	3,100	1	167,213	35,293

MONTHLY PUMPING REPORT - AMBATALE
MONTH OF JUNE 2012

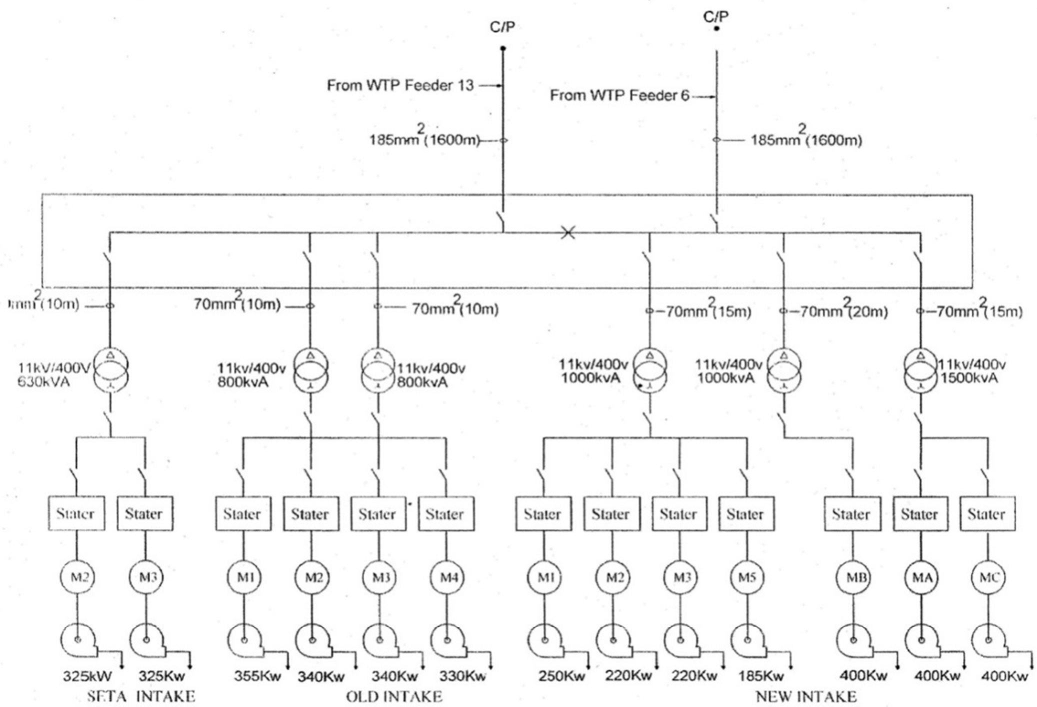
Date	Jubilee	Dehiwala	Elli House	Elli House(N)	Maligakand	CH (Old)	CH (New)	KRB (CH)	Kolonnawa
	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day
1-Jun-2012	83,486	118,092	65,600	30,957	82,300	40,300	-	131,948	23,542
2-Jun-2012	65,480	115,649	53,600	33,052	81,600	40,600	-	122,367	34,707
3-Jun-2012	122,246	114,049	61,500	34,937	81,000	40,500	-	123,891	35,497
4-Jun-2012	122,735	117,250	67,100	31,191	83,900	40,400	-	115,103	35,209
5-Jun-2012	118,711	114,985	62,200	34,811	80,600	39,000	-	119,658	33,666
6-Jun-2012	119,249	115,651	62,800	31,507	82,100	40,200	-	108,427	35,105
7-Jun-2012	120,285	115,518	64,100	33,361	82,500	39,800	-	132,494	35,360
8-Jun-2012	120,039	115,484	68,500	32,382	82,600	39,900	-	120,956	34,769
9-Jun-2012	120,930	115,308	71,800	33,088	81,700	39,400	-	126,650	34,908
10-Jun-2012	121,048	116,570	68,600	33,217	82,800	40,300	-	120,840	34,972
11-Jun-2012	119,675	112,591	71,700	33,293	82,100	38,400	-	122,814	34,699
12-Jun-2012	121,209	117,049	69,900	33,725	83,200	42,100	-	126,016	35,482
13-Jun-2012	118,846	114,350	57,100	33,077	82,400	41,400	-	120,080	34,906
14-Jun-2012	119,970	96,655	65,300	33,352	84,000	40,600	-	120,428	35,542
15-Jun-2012	126,987	119,816	62,900	31,899	81,200	40,500	-	124,921	34,472
16-Jun-2012	128,301	114,235	68,300	34,791	82,600	41,600	-	117,130	34,435
17-Jun-2012	133,081	116,211	55,900	33,680	82,800	42,400	-	127,689	35,318
18-Jun-2012	127,758	114,016	72,100	32,403	82,000	40,200	-	118,600	34,554
19-Jun-2012	131,199	113,860	58,000	33,301	84,200	42,500	-	124,101	35,111
20-Jun-2012	126,967	114,715	67,500	33,992	81,800	40,300	-	126,485	34,853
21-Jun-2012	130,344	115,700	68,400	32,989	82,600	40,600	-	125,159	35,098
22-Jun-2012	131,926	114,237	63,500	33,059	82,500	41,100	-	152,819	34,692
23-Jun-2012	132,077	114,535	65,300	33,195	82,700	7,100	-	167,097	34,910
24-Jun-2012	136,212	114,717	61,100	33,157	83,600	-	-	167,097	35,446
25-Jun-2012	135,389	112,749	72,200	32,608	84,400	-	-	170,826	34,971
26-Jun-2012	134,350	109,128	59,800	33,624	81,700	-	-	163,458	35,215
27-Jun-2012	135,265	119,797	62,800	33,135	82,000	-	-	177,817	34,595
28-Jun-2012	136,174	115,388	55,500	33,298	83,500	-	-	173,278	35,681
29-Jun-2012	136,510	114,638	66,800	33,269	82,900	-	-	174,668	35,328
30-Jun-2012	135,316	113,194	65,400	33,011	82,400	-	-	166,175	35,097
AVG	123,726	114,538	64,510	33,112	82,523	39,096	-	136,300	34,605

MONTHLY PUMPING REPORT - AMBATALE
MONTH OF MAY 2012

Date	Jubilee	Dehiwala	Elli House	Elli House(N)	Maligakand	CH (Old)	CH (New)	KRB (CH)	Kolonnawa
	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day	m^3/Day
1-May-2012	117,942	113,100	74,300	33,120	80,700	33,000	-	114,154	34,262
2-May-2012	117,980	110,319	67,800	32,659	81,200	33,800	-	114,976	34,469
3-May-2012	120,875	120,885	77,800	33,234	82,200	33,800	-	126,662	35,147
4-May-2012	120,875	120,885	77,800	33,234	82,200	102,400	-	82,590	34,735
5-May-2012	116,616	115,237	64,800	32,916	81,700	77,800	-	73,335	34,735
6-May-2012	120,057	114,864	76,800	33,796	82,400	101,300	-	73,532	35,397
7-May-2012	120,823	114,855	68,900	32,085	82,400	102,400	-	72,035	35,364
8-May-2012	111,780	111,331	70,800	32,916	81,000	99,800	-	72,453	32,505
9-May-2012	119,660	119,386	67,000	32,516	81,700	100,900	-	72,221	34,792
10-May-2012	120,082	110,846	65,500	34,291	83,200	100,900	-	72,521	35,443
11-May-2012	123,930	121,922	75,600	31,369	83,000	99,700	-	72,798	35,574
12-May-2012	118,226	116,928	71,900	33,363	81,400	99,400	-	77,264	34,263
13-May-2012	123,458	117,418	66,900	34,768	82,400	100,600	-	71,988	35,200
14-May-2012	118,408	114,286	77,300	31,320	82,400	99,400	-	72,987	34,762
15-May-2012	120,810	114,458	72,900	35,377	82,800	100,400	-	71,204	35,167
16-May-2012	122,440	116,751	76,000	30,590	81,400	97,900	-	71,912	34,358
17-May-2012	122,112	116,149	71,300	34,376	82,600	99,400	-	79,694	35,279
18-May-2012	124,190	117,560	61,400	31,916	80,300	99,500	26,350	40,631	34,753
19-May-2012	120,636	118,458	76,000	33,066	85,600	98,200	-	82,676	34,698
20-May-2012	123,700	117,304	77,600	33,339	83,000	99,800	-	79,600	35,409
21-May-2012	119,548	115,614	75,700	33,027	81,600	97,000	-	89,274	34,644
22-May-2012	123,289	121,199	77,800	33,140	82,500	95,800	-	81,190	35,143
23-May-2012	120,473	113,157	70,500	33,183	81,500	96,600	-	82,238	34,859
24-May-2012	117,055	108,940	75,100	33,066	82,100	98,200	-	80,472	31,611
25-May-2012	120,851	120,363	43,700	31,974	80,800	96,900	23,231	45,912	35,474
26-May-2012	117,837	114,725	25,200	24,852	81,800	99,200	-	76,050	34,250
27-May-2012	119,968	112,419	73,100	33,174	82,600	94,800	10	71,582	34,665
28-May-2012	121,064	114,428	47,000	32,909	82,900	49,100	-	187,295	34,596
29-May-2012	123,232	115,202	70,100	33,904	84,100	41,100	23	126,226	35,817
30-May-2012	115,996	111,020	56,200	32,130	79,800	39,300	-	116,144	33,849
31-May-2012	120,867	115,332	70,000	35,354	82,900	40,300	-	131,948	35,713
AVG	120,154	115,656	68,477	32,805	82,006	84,797	12,404	86,567	34,740

Appendix F: Existing Power Arrangement of Raw Water Intake

EXSISTING POWER ARRANGEMENT OF RAW WATER INTAKE



EXSISTING POWER ARRANGEMENT OF MALIGAKANDA ELI HOUSE AND CHURCH HILL