THE DEVELOPMENT OF PERFORMANCE MEASURES IN THE MANAGEMENT OF WATER UTILITIES IN SRI LANKA

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Declaration

I declare that this is my own work and this thesis does not incorporate without acknowledgement 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.

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Abstract

The Development of Performance Measures in the Management of Water Utilities in Sri Lanka

In developing countries, water utilities bear massive challenges, in supplying pipe-borne water. National Water Supply & Drainage Board (NWSDB), the sole supplier of safe drinking water in Sri Lanka, under the Ministry of City Planning & Water Supply, increased its piped water services to cover 34% of population in 2014. NWSDB's Corporate Planning Division presents its performance, showing access to safe drinking water, via Annual and Key Performance Indicator (KPI) Reports, using different ratios with eleven variables. Performance is imperative for the betterment of a water utility. Recognizing this fact, the study proposes an alternative way of presenting performance of NWSDB, because single ratios do not provide comprehensive explanations about performance of water utilities.

Therefore, this study focused on the productive efficiency concept under parametric approach to estimate technical efficiency using Stochastic Production Frontier (SPF) technique as the best Industry Practice. First, SPF model was proposed for NWSDB. Then, selected regional manager's centres producing pipe-borne water were analysed using SPF model, to check its inefficiency. The test statistics found that SPF model was an inefficiency model. Finally, NWSDB was analysed using SPF model and overall mean technical inefficiency and technical efficiency were estimated for the period of 2010, 2011, 2012, 2013 and 2014. The SPF model was analysed using maximum likelihood iteration method to estimate the elasticity values of parameters, using the 'STATA' software package, specially designed for stochastic frontier models.

Study confirmed NWSDB manages a similar technical efficiency level annually. Technical efficiency trend showed the increase occurring at a diminishing rate. Finally, the inefficiency model derived from the SPF model was proposed to NWSDB, which clarified the significance of variables affecting NWSDB's production, directly or indirectly, to managers etc. This SPF model allowed NWSDB to estimate mean technical efficiency for presenting performance reports as an alternative.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AIP	-	Annual Implementation Programme
CBO	-	Community Based Organization
DEA	-	Data Envelop Analysis
KPI	-	Key Performance Indicators
MDG	-	Millennium Development Goals
MI	-	Management Information
NWSDB	-	National Water Supply & Drainage Board
OPI	-	Overall Performance Indicator
RSC	-	Regional Support Centres
SCFA	-	Stochastic Cost Frontier Approach
SLNWP	-	Sri Lanka National Water Partnership
SPFA	-	Stochastic Production Frontier Approach
STATA	-	Statistic / Data analysis software
UN	-	United Nations
US	-	United States
WHO	-	World Health Organization

CHAPTER 1

INTRODUCTION

1.1. Background

The World Bank Annual Report states that development of any country's social status directly relies on fulfilling the basic needs of its community (The World Bank, 2013). It basically depends on infrastructure development of a country. Infrastructure development of any country enables the quality of life of its people by providing basic facilities like transport, communication, sewerage-facilities, water supply facilities and electricity systems (The World Bank, 2013). By 2030, world population is forecast to be 8.4 billion (United Nations, 2013). To cater to such a population, Governments worldwide, forecast that, global infrastructure development demand requires US$ 57.3 Trillion in investment by 2030 (Miller, 2013). To meet this demand, the need to set up necessary infrastructure, enabling development for the access of safe water has been identified as a priority (The World Bank, 2014).

However today, almost 27 per cent of countries are seriously off track with the global Millennium Development Goals (MDG 7), especially in water targets (The World Bank, 2014). Further, 748 million people still draw their water from an unimproved water source. Due to the lack of access to safe drinking water, critical health issues arise with water related diseases (WHO, 2014). In addition, annual economic losses in billion- hundred-dollars (US$ 260 billion annually) are caused, by lack of access to safe water (Sy, Warner & Jamieson, 2014). The above data proves that the current safe drinking water supply sector is inadequate and has failed to deliver the expected benefits to society. On the other hand, identifying the demand for drinking water, Governments worldwide recognise the significance of providing funds for the water supply sector, within their total infrastructure development investment plan by 2030, allowing for the population increases, urbanization, rising incomes and industrial growth (Miller, 2013).

In line with global water needs, water supply industries around the world have critically evaluated the water utilities with the aim of enhancing performances in the subject area of efficiency and quality achievements in the last two decades (The World Bank, 2014). Further, to improve the quality of water services and enhance public accountability, the measurement of efficiency and performance has been identified as important indicators. This is a challenging task. Unfortunately, the water supply industry is still struggling with problems of efficiency and quality of water utilities to meet the growing demand (Miller (2013) and The World Bank (2014)). This indicates that further investigation is necessary into the performance assessment of water supply utilities in terms of efficiency and productivity criteria. This is because, the analysis of efficiency in the management of water services offers valuable information for managers and regulators of this service to fulfil the requirement of domestic safe water and non-domestic safe water demands (Worthington, 2011).

Therefore, the principal aim of this study is to develop the performance measures in the management of water utilities in Sri Lanka with quantitative figures. This would provide the best industry practice developed world wide, over many decades for presenting performance of the water utilities, because comprehensive information about the performance level of the water services will help regulatory authorities to encourage efficient performance.

1.2. Research Problem Identification

As mentioned in section 1.1, the analysis of performance in line with the management of water utility is considered as an important practice worldwide (Miller, 2013). In order to measure performances in water utilities, the best performance and reporting systems should be adopted (Berg, 2010). The performance measuring techniques which include simple ratio analysis, ordinary least squares (OLS) regression, frontier analysis and total factor productivity indices have been used in overseas studies for water utilities (Coelli and Walding, 2006; Coelli, 2008 and Berg, 2010). However, Berg (2010) argued that performances presented through single ratios of a utility have not given comprehensive descriptions about the performance of any particular utility. Therefore, different techniques were introduced to water utility sectors because, internationally, managers and regulators of water sector recognised the importance of measuring performances of water utilities.

Unlike other countries, in Sri Lanka, National Water Supply and Drainage Board (NWSDB) acts as the largest public water utility provider and has the main responsibility to develop, provide, operate and control an efficient, coordinated water supply and distribution system for the public, (domestic and industrial), while achieving customer satisfaction by identifying their values and total needs (Corporate Plans for NWSDB, 2012-2016; 2012). As the private participation is very low in supplying piped borne water (covers 1.3 per cent (%) of total population), NWSDB has created a monopolistic nature in the country's water industry (summary of progress status on the corporate action plans, NWSDB, 2014). Due to this monopolistic nature of the NWSDB, there should be a systematic approach to assess the performance of NWSDB, as the major pipe borne water producer in Sri Lanka.

Currently, NWSDB uses different Key Performance Indicators (KPI) to demonstrate the performance of NWSDB. These KPI represents mainly four indicators such as operational indicators, financial indicators, customer service indicators and service indicators. The KPI report presents eleven ratios using eleven observations as performance indicators of NWSDB (KPI report, NWSDB, 2014). Each KPI reflects only one input and one output level by using simple ratio analysis, percentage and average analysis, for example. It is difficult to gain an overall view of the performance of NWSDB because KPI does not include all information on the inputs and outputs used by the firm as mentioned in Berg (2010).

In addressing the above problem, Jayawikrama (2014) tried to develop an Overall Performance Indicator (OPI) instead of KPI to demonstrate the performance of NWSDB. This OPI combines the mean value of financial, customer service and service indicators, as a single average indicator (average of all three indicators) for the relevant year of study. This OPI represents as a single mean value of performance achieved by NWSDB yearly for the categorized four indicators. For an example, Jayawikrama (2014) illustrated that the value of OPI for the year 2008 is 9.438 while 7.386 is for 2013 Island wide. Jayawikrama (2014) also tried to develop an overall view of the performance of NWSDB with the mean value of developed OPI. Finally, this study concluded that the OPI for a particular year should get a lower value than the previous year. The problem is, the above two values 9.438 and 7.386 gave different meaning. In this situation, it is very clear that OPI method developed by Jayawikrama (2014) is not suitable to illustrate the performance of NWSDB, because there is no best OPI value to compare with the current value.

The above KPI and OPI give simple symptoms to managers, decision makers and key stakeholders about performance levels achieved by NWSDB, because OPI also gives some indication to compare current value with the previous year. Further, KPI and OPI indicators follow the set targets by NWSDB and find the deviation using ratios. The above performance comparisons and trend directions to potential key areas provide the simplest way to demonstrate the performance of NWSDB as mentioned earlier. According to IBNET (International Benchmarking Network for Water and Sanitation Utilities), partial measures are practiced by well-managed organizations as this is the simplest way to carry out the performance of water utility [Danilenko, van den Berg, Macheve & Moffitt (2014)].

The above circumstances call for the development of a more reliable methodology, to present the performance for NWSDB, instead of developing KPIs and OPI's. As mentioned earlier, performance of water producers can be evaluated using different efficiency concepts. In this context, this study is trying to give an alternative way in which the NWSDB can employ a performance measure with quantitative evidence in the subject area of efficiency. Further, there has been a lack of research in the area of evaluating efficiency in Sri Lankan water utility sector up to now. This situation stimulated this study, to investigate the efficiency level of NWSDB, considering all variables together, instead of developing KPI or OPI. It is very relevant and important to develop an alternative method to evaluate and measure the performance for NWSDB as a management tool. In this context, this study focuses simply on efficiency analysis of NWSDB as a performance measure, because ratios which represent the performance of a utility have not given comprehensive description about performance of a utility.

Finally, the outcomes may be accepted by management, regulators, policy makers, utility providers and the public at large, in order to achieve an efficient, productive and a sustainable water supply sector in the 21st century. This study will provide a simple overview for implementing an effective performance-based measurement system within a public water utility in Sri Lanka.

1.3. Aim and Objectives

The aim of this study is to analyse the efficiency level of NWSDB using the efficiency estimation model.

More specifically, the objectives of this research are:

- To review existing research on performance measurement within the spectrum of efficiency concepts in water utilities.
- To review methodology on efficiency measurement techniques and screen the best fit industry practice.
- To develop the efficiency estimation model for NWSDB and test the model for regional managers' centres which produce pipe borne water.
- To analyse and estimate efficiency level (point estimated value) for NWSDB using the developed estimation model.

1.4. Research Methodology

Primarily, literature review was carried out with the view of gaining a better understanding of methodologies used for efficiency and performance measures of water supply industry. This informs the methods used in previous work on water utilities in the world. From previous work knowledge, a relevant efficiency measurement technique was selected to find the basic model and its specification.

Then, the basic model relevant to NWSDB was developed depending on the observable data. The relevant variable data was selected carefully based on KPI variables which are published in the NWSDB yearly reports. For this study, the raw data was collected through the monthly observations directly from NWSDB for the period from 2010 to 2014.

After developing the best fit efficiency estimation model with relevant variables, inference of this model is estimated using a developed software package which is utilised worldwide by the utility sector. Thereafter, this model is tested using hypothesis techniques. If the developed model is accepted, technical efficiency is estimated using the developed model. A detailed analysis is described in Chapter 4. Further, the outcomes gave a lead to identify the significant input data which can control the efficiency measures. Then more valuable input data were discussed as significant data will aid policymakers, project managers and practitioners in the water supply sector in Sri Lanka. However, this study contains considerable discussion of the data which control the efficiency level of water utilities and hence the degree to which these measures should be used.

1.5. Scope and Limitations

The scope of this study is to develop an efficiency estimation model for NWSDB as an alternative way of presenting performance using data for the five years from 2010 to 2014. In this analysis, pipe borne drinking water directly supplied from NWSDB is focused without considering the other means of supplying water through small rural water supply schemes using natural springs, protected dug wells, tube wells and rainwater harvesting systems. Improved water sources such as vendor-provided water, bottled water, tanker trucks and unprotected wells are excluded in this study. The relevant data for this study was collected directly from NWSDB reports and the database.

This research is based on the performance data from monthly observations for pipe borne drinking water supplied directly through NWSDB schemes only. Here, data based on KPI are collected through 11 Regional Support Centres (RSC) and their 24 regional managers' centres (Regions). All the regions are considered as an independent organization which produces and delivers water through piped network and earn revenue for NWSDB.

1.6. Chapter Organization

This study is organized into five chapters as follows:

Chapter One: Chapter one carries the introduction, the research problem identification, aim of the research, research objectives, scope and limitations of the study.

Chapter Two: This chapter provides a review of literature on efficiency and performance-studies related to water utility.

Chapter Three: This chapter explores the methodology practiced in water utility sector and the model used for data analysis.

Chapter Four: Describes the sample, data collection techniques, analysis of the model, estimation and findings.

Chapter Five: The final chapter presents the conclusions derived from the key findings of the study. It also offers recommendations and directions for further research.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

The purpose of this chapter is to review the empirical literature on performance and efficiency measures in water utilities as a producer of drinking water. It reviews works on different measurement techniques used, internationally and locally at various levels. Further, this chapter also presents the methodology and techniques used in the research, the sample, input and output data, outcomes of past studies and information on the country, where the research is carried out. These are summarized in Table 2.5. Emphasis is placed on the specification of inputs and outputs of performance and efficiency studies, which have been conducted earlier. Further, some of the limitations associated with the availability of suitable data are identified. The empirical literature on performance and efficiency measurement in water utilities were searched using Google Scholar to locate books and book chapters. However, unpublished research, conference proceedings, unpublished journal articles, working papers and government and non-government reports are also considered in the research. References therein helped to identify other relevant articles. In addition, NWSDB website and published reports in NWSDB library are also reviewed in this study.

The chapter comprises of six sections. Section 2.2 demonstrates an overview of the Sri Lankan water utility sector. Section 2.3 discusses the definition of efficiency. Section 2.4 reviews literature on efficiency and performance measurement of water utilities. Section 2.5 discusses Input-output relationship of past studies. Section 2.6 shows the chapter summary.

2.2. An Overview of the Sri Lankan Water Utility Sector

Unlike other countries, infrastructure development in water utilities in Sri Lanka has grown significantly with urbanization, population increases and industrialization needs (Corporate Plans for NWSDB, 2007 - 2011; 2007 and 2012 - 2016; 2012). NWSDB as a government agent in Sri Lanka covers both pipe water supply (drinking water) and sewerage services. The NWSDB, established in 1975, is the principal agency for supplying piped water in Sri Lanka (Corporate Plans for NWSDB, 2007 - 2011; 2007). In line with Millennium Development Goals (MDG) and the government set targets, Sri Lankan government has allocated a considerable amount of capital by setting the targets of achieving 85% of the population with access to safe drinking water by 2015 and 100% by 2025 (Corporate Plans for NWSDB, 2007-2011; 2007 and 2012-2016; 2012). These capitals are funded through government local funds, foreign donors' loans and grants while minor rehabilitation and renovation is financed through internally generated funds of NWSDB.

Presently, the NWSDB operates 20 large scale donor-funded and 37 small & medium scale Water Supply Projects, which are in progress or in various stages of implementation throughout the country (Corporate action plan, NWSDB, 2015). The operations and maintenance of treatment plants, billing, collection and other policies are implemented through its regional offices. Water consumers are charged a fee monthly, based on volumetric pricing, and the Board administers the same pricing policy across the country.

As the private participation remains low up to now, the sustainable access of drinking water needs of the country is met by piped water supply, small rural water supply schemes using natural springs, protected dug wells, tube wells and rainwater harvesting systems (summary of progress status on the corporate action plans, NWSDB, 2014). In addition, the improved water sources as vendor-provided water, bottled water, tanker trucks, unprotected wells and springs are also used as drinking water sources (Corporate Plans for NWSDB, 2007- 2011; 2007). Recently, the sustainable access of safe drinking water percentage by population in 2014 is shown in Table 2.1 and Figure 2.1.

Table 2.1: The access of safe water percentage by population in 2014

Total access to safe water	**Access to safe water by Protected wells**	**Piped water directly supply from NWSDB**	**Piped water supply from Community Based Organizations (CBO)**	**Access to safe water by Tube wells/Hand pumps**	**Piped water supply from others**	**Access to safe water by Rainwater harvesting and others**
84.60%	36.60%	33.40%	9.60%	3.20%	1.30%	0.50%

(Source: Summary of progress status on the corporate action plans, NWSDB, 2014)

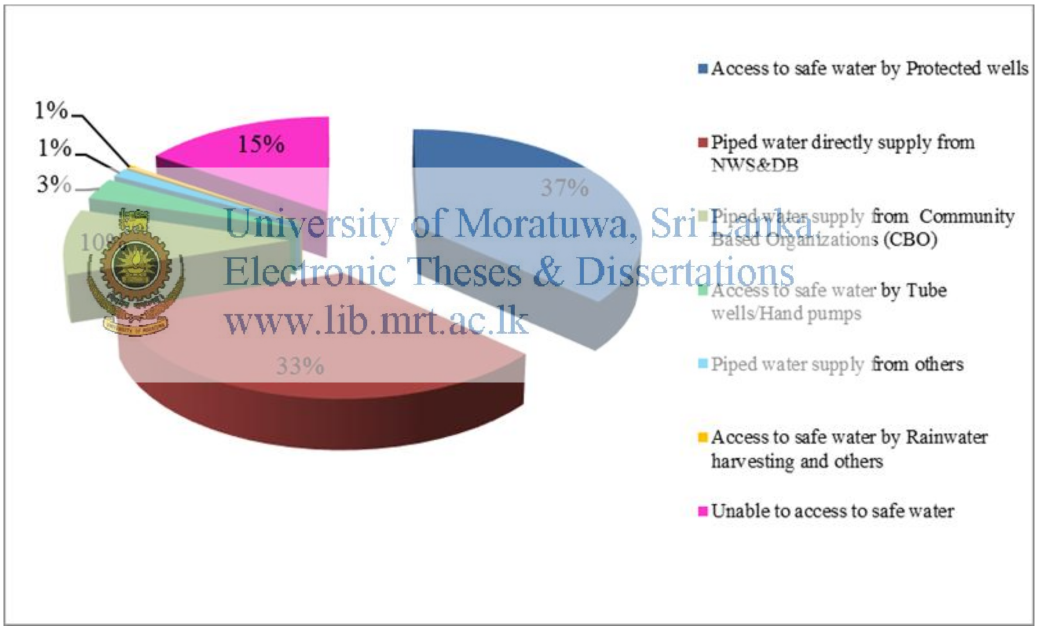


Figure 2.1: Percentage of the population which access safe water and unable to access safe water in 2014.

(Source: Summary of progress status on the corporate action plans, NWSDB, 2014)

According to Table 2.1, the total pipe borne water supply coverage (44.3%) is achieved directly from NWSDB (33.4%), Community Based Organizations (9.6%) and other pipe water supply connections (1.3%). All other means of access for safe water coverage is equal to total pipe borne water supply, through protected wells, tube wells, hand pumps and rain water harvesting systems.

Even though the total piped water supply coverage was 44.3 % of the total population by 2014, direct coverage of piped water supply from the NWSDB is 33.4% of the total population (Summary of progress status on the corporate action plans, NWSDB, 2014). The access for piped safe drinking water, directly supplied through NWSDB remains low as a percentage of the population, as at 2014, while other means of access for water is 51.2% of the population as at 2014. It shows that total pipe borne water supply coverage remains low up to now. Almost half of the drinking water needs are met through protected wells, tube wells, hand pumps and rain water harvesting systems. On the other hand, Figure 2.1 also shows that, “unable to access safe water” coverage from the total population in 2014 was 15%.

However, the demand for water is growing rapidly with the increase of projected population to 25 million by 2030 in Sri Lanka, while the urban population is expected to increase from the current 5.6 million to 15 million, i.e., from 30 per cent to 60 per cent (United Nations, 2015). As a result, there is pressure, to meet the demand of water supplies and infrastructure needs of the increasing population. Therefore, the overall target of the corporate plan of NWSDB, as the main provider of safe drinking water in Sri Lanka, is to achieve pipe borne water supply for 44 % of the total population of Sri Lanka by 2016 and 60% by 2020, solely through NWSDB schemes (Corporate Plans for NWSDB, 2012-2016; 2012). Table 2.2 describes the progress achieved by NWSDB through pipe borne domestic water supply as a percentage of population increase and as a percentage of Non-Revenue Water (NRW).

Table 2.2: Water supply coverage with the population increase and NRW (%).

Year	2006	2007	2008	2009	2010	2011	2012	2013
Population	20,027,644	20,227,921	20,430,200	20,634,502	20,840,847	20,861,045	21,069,655	21,280,352
Pipe borne domestic water connection by NWSDB (No's)	892,012	976,555	1,078,178	1,151,933	1,248,176	1,337,181	1,465,350	1,577,596
Domestic population covered through pipe borne treated water connections by NWSDB only	3,568,048	3,906,220	4,312,712	4,607,732	4,992,704	5,348,724	5,861,400	6,310,384
Pipe borne treated water supply connected Coverage (%) by domestic population under water schemes operated by NWSDB only	17.8	19.3	21.1	22.3	24.0	25.6	27.8	29.7
Total pipe borne water supply (NWSDB, CBO & Others) Coverage (%) by total population	29.8	32	34	36.9	39.2	42	43.5	43.7
Non-Revenue Water (NRW) (%) of total treated water production	34.37	33.09	32.13	31.1	31.6	30.5	30.3	30.24

Source: Annual Implementation Programme (AIP) Reports for NWSDB, 2006-2013 and Management Information's (MI) Reports for NWSDB, 2006 - 2013. Corporate Plans for NWSDB, 2007- 2011; 2007 and 2012-2016; 2012. Annual Report for NWSDB, 2007- 2010.

Note: Domestic population is calculated by multiplying number of domestic connections into 4.0 instead of 3.91(Family size) as mentioned in summary of progress status on the corporate action plans as at end of year 2014.

According to Table 2.1 and Figure 2.1, it is very clear that total pipe borne water supply connected coverage (%) by total population is growing at a low increasing rate. Unfortunately, the Island wide Non-Revenue Water (NRW) is on average 31% of the piped water production (Table 2.2). It means that the balance 69% of the total piped water production is equal to the water supply of 33.4% of the total population (the direct supply coverage from the NWSDB in 2014) as described in Table 2.1.

This shows that there should be a discussion on alternative ways for achieving efficiency and serious attention must be paid to increase the efficiency of water supply. Moreover, Table 2.3 and Figure 2.2 show that the gap between total piped water connections to consumers and loss of water connections due to NRW is increasing at an increasing rate. The data for Table 2.3 and Figure 2.2 depends on NRW data presented in Table 2.2.

Table 2.3: Total piped water connections and loss of connections due to NRW

Year	Total piped water connection to customers by NWSDB (No's) / Year	Loss of consumer water connections due to NRW (estimated) / Year
2006	989,395	518,139
2007	1,078,892	533,560
2008	1,186,931	561,899
2009	1,266,328	571,593
2010	1,353,573	625,334
2011	1,449,301	669,560
2012	1,587,663	690,189
2013	1,707,742	740,282

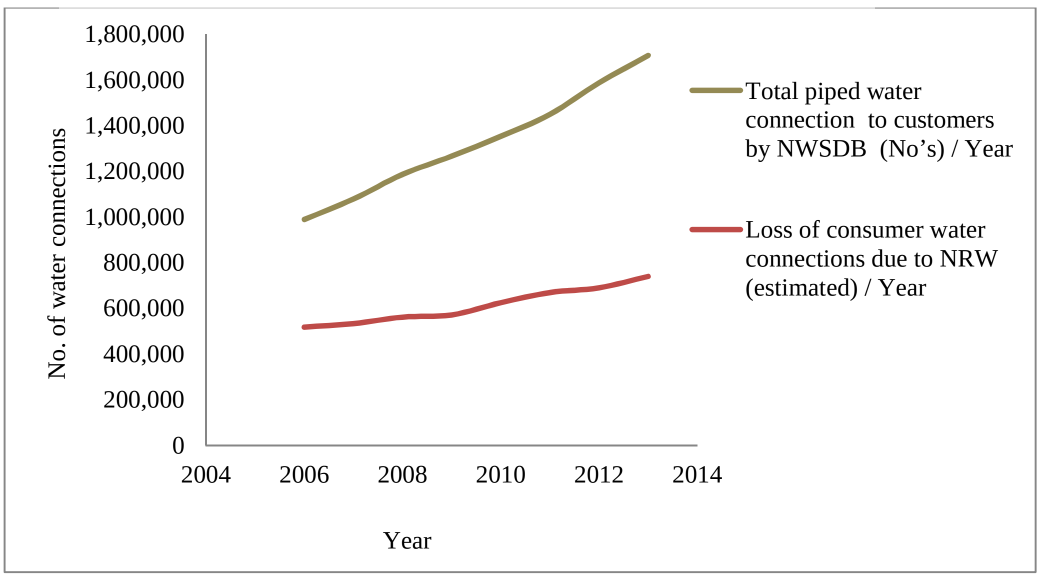


Figure 2.2: Total Annual piped water connections and loss of connections due to NRW by NWSDB (No's)

Unfortunately, the loss of connections due to NRW is still increasing annually, as mentioned in Table 2.3. It is graphically shown in Figure 2.2. The increase of NRW is caused due to leakages (Physical losses), Illegal connections (Unauthorized consumptions), administration losses and free water supply to stand post and state houses (Unbilled but actual water consumptions) (Annual Report, NWSDB, 2010). Such losses as explained above, of treated water are not accounted for by NWSDB and therefore revenue is not generated. People do not have access for 31% of pipe water production. This shows that additional cost has to be borne by existing customers for every unit of consumption. Additional cost due to NRW indicates growing trend up to now (Annual Report, NWSDB, 2010). According to the Corporate Plan of NWSDB 2012, there had been a long delay for providing new connections. As a result, NWSDB received no revenue and undue competition among consumers and applicants for new connections had prevailed. This creates a gap between demand and supply that continues to worsen as the country faces growing demand for piped water through population increase and rapid urbanisation.

This issue regarding water production and supply emphasises that efficiency should be increased to cater for the demand which has been created due to the population increase. Because of the monopoly of a public service provider like NWSDB, there should be a systematic approach to assess the efficiency and performance. Therefore, understanding the current level of efficiency through regional-wise efficiency levels is very important in order to have a timely review for the successful achievement of goals, objectives and set targets using different methodologies. Since, internationally, evaluation of water utilities with the aid of efficiency term is considered as a management tool as mentioned in section 1.2. Instead of introducing new projects through large scale investments (through Foreign Funded Loans) to cater for demand, it is possible to identify the significant factors to increase efficiency without increasing the inputs regional-wise and give that information to the management, enabling it to make the necessary changes.

However, one of the major objectives of NWSDB is to ensure a high degree of water security with respect to quality and quantity, to meet the demand of the country for water through all water supply systems. The mission of the NWSDB is to serve the Nation by providing water through a sustainable system and to provide sanitation solutions ensuring total user satisfaction. In order to achieve this objective, NWSDB has to increase efficiency of its piped water supply to the people. However, according to current evaluations, it was observed that the level of satisfaction with regard to meeting the demand for water supply was not satisfactory for NWSDB (Annual Report, NWSDB, 2010).

2.2.1. KPI and OPI

The NWSDB measures its performance by using simple ratio analysis, percentage and average analysis. These ratios are called partial productivity ratios. The productivity ratios are sometimes known as the partial productivity index (Marques & Monteiro, 2003). NWSDB develops the partial performance ratios as Key Performance Indicators (KPIs) to present its performance annually, considering eleven key observational variables obtained monthly from each Regional Support Centre (RSC). The four main KPIs are Service Indicator, Operational Indicator, Financial Indicator and Customer Service Indicator. Service Indicator presents two KPIs; Piped Water Connected Coverage (%) and Water Quality (%). Operational Indicator demonstrates four KPIs; Non-Revenue Water (%), ratio of Staff/1,000 Connections, Defective meters/1,000 connections and Estimated bills per 1,000 connections. Financial Indicator shows four indicators; Energy Cost/cum of water produced (Rs./cum), Accounts Receivable Period (months) (excluding disconnections), Stock Efficiency and Operating Ratio. Finally, Customer Service Indicator represents the Customer Complaints/1,000 connections. These observational data cover all the key activities of NWSDB.

The observational data needed for the 11 variables to calculate KPIs are collected monthly through all 24 regions. The average values of monthly observations are used to calculate the KPI for each Regional Manager's Centre (all Regions) yearly. The Island-wide KPI is calculated with the average KPI value of the 11 RSCs. Thus, there are 11 Island-wide KPIs. Each KPI is presented graphically for the 11 RSCs in a column chart indicating the previous year status, target performance and actual performance achieved respectively. Each of these 11 KPIs behaves exclusively by itself and shows a partial performance. These partial performance indicators do not show the overall performance effectively.

Therefore, Jayawikrama (2014) identified the situation and proposed Overall Performance Indicator (OPI) to NWSDB. Instead of 11 KPIs, three major performance indicators such as service indicator (Y_1), financial indicator (Y_2) and operational indicator (Y_3) were developed to present performance of NWSDB. The three Indicators, (Y_1), (Y_2) and (Y_3) were developed using regression line. Each regression has proposed four independent variables. Each regression estimates coefficients for independent variables. Then weighted average method was applied to estimate the coefficients of independent variables and using regression analysis (Y_1), (Y_2) and (Y_3) were evaluated. Finally, average value of (Y_1), (Y_2) and (Y_3) was developed as the OPI, a single value for three indicators yearly. Jayawikrama (2014) concluded that OPI for any particular year should be getting a lower value than the previous year. The OPI gave a single figure which cannot describe a whole organization and its effect. Thus, it can be seen that KPI and OPI do not systematically show the overall performance of NWSDB.

2.3. Definition of Efficiency

There are many different terms employed to define efficiency. This section discusses briefly a modern definition on efficiency measurement. The fascinating reasons for measuring efficiency of a firm, which is in the operating environment may be due to three factors; first, identification and separation of controllable and uncontrollable sources of performance variation; second, the fact that macro performance depends on micro performance; third, producers are evaluated with efficiency measures because it acts as a management tool (Fried, Lovell & Schmidt (Eds.), 2008). The literature on the topic of efficiency is wide-ranging and often unclear. The following are some observations of efficiency related to the production environment.

The efficiency of a utility firm is demonstrated at two efficiency boundaries such as technical efficiency and allocative efficiency (Zschille & Walter, 2012). In a production process, a production function specifies the maximum output that can be produced for a given amount of inputs (Bhattacharyya et al., 1995). Thus, the efficiency under production possibilities is called “technical efficiency”. Further, efficiency in the case of technical efficiency in a production process is described similarly, where, a combination of inputs are used to produce a larger output quantity using various production isoquants (Hirschey, 2009). Then, it is evident that the above technical efficiency measures can be developed as either input- or output-oriented efficiency (Zschille & Walter, 2012). Under input orientation, the efficiency scores describe the ratio of minimum inputs for fixed outputs, and under output orientation, maximum outputs for fixed inputs.

Fried et al., (2008) refers to Koopmans (1951) study, which provided a formal definition for technical efficiency: a producer is technically efficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input, and if a reduction in any input requires an increase in at least one other input or a reduction in at least one output. Thus, a technically inefficient producer could produce the same outputs with less of at least one input, or could use the same inputs to produce more, at least one output.

The efficiency under the behavioural goal of the producer is called an “economic efficiency”. In general terms, economic efficiency is its difference and deviation to an appropriate economic frontier from its goal. In this event, efficiency is measured by comparing observed and optimum cost, revenue, profit, or whatever goal the producer is assumed to pursue, and is subjected, to any appropriate constraints on quantities and prices (Fried et al., 2008). Economic efficiency has technical and allocative components. However, Hargreaves, Parr, Lay and Weeks (2006) demonstrated some frequently used efficiency concepts in Table 2.4 such as:

Table 2.4: Efficiency Concepts

Concepts	Definition	Concepts
Productive efficiency	This refers to the efficient production of a given set of outputs, sometimes characterized as being on the production possibility or efficiency frontier. For a firm, this is achieved when it combines factors of production so that the ratio of the marginal products of any pair of factors is equal to the ratio of their prices.	**Engineering efficiency** – a partial measure, the ratio of output to the input of a single factor (e.g. miles per litre of petrol). **Technical efficiency** – the ratio of output to the physical amount of all factors involved in production. Economists also call this "X efficiency". **Economic efficiency** - the ratio of output to the value of all the inputs. A firm is efficient if there is no way of using a lower value of inputs.
Allocative efficiency	Reflects an efficient choice between positions on the efficiency frontier. The economy or a company is efficient in allocative terms if, as well as being on the efficiency frontier, the marginal cost of producing any product is equal to its price.	Producing the right outputs in the right way – allocative efficiency means that the sum of consumers' and producers' surplus is a maximum. The output in a market with perfect competition is allocatively efficient.
Dynamic efficiency	The system produces desirable process and product innovations and flexible responses to changes in demand.	Other things being equal, regulation limits dynamic efficiency.
Comparative efficiency	A regulatory term referring to a range of techniques to use to compare regulated entities and use the best performer as the standard for achievement by the others	Absolute efficiency – meaningless in this context Comparative competition – the way in which companies respond to the incentives introduced when regulators publish performance league tables. Catch-up – the extent to which the laggards catch up with the leaders in comparative competition

(Source: Hargreaves et. al., 2006)

2.4. Review of Efficiency and Performance Measurement of Water Utilities

Internationally, most water utilities have demonstrated efficiency and their performance as a customary practice to provide meaningful information for improvement of the organisation and to improve the design of public policies (Horn & Saito, 2011). In previous studies, different types of water utilities such as water-only companies and water and sewerage companies seemed to have used different types of efficiency measurement techniques. However, Table 2.5 summarizes a selection of international studies carried out previously, which report evidence on firm efficiency and performance measurements from different countries such as the UK, the US, some Latin American countries, Australia, Germany, Malaysia, Slovenia, Spain, Italy, Brazil, Peru, Portugal, some African countries, some Asian countries including Japan and India and some countries in the Pacific region. The review does not include any Sri Lankan studies regarding the analysis of water utility performances under the terms of efficiency and performance metrics because it was unable to find any Sri Lankan studies in the published literature.

Table 2.5: Review of efficiency and performance measurement of water utilities

No	Technique used	Independent Variable	Dependent Variable	Sample units considered	Outcomes	Country	Source
1	**Stochastic frontier analysis (production function)**	Volume Water input, cost of energy, labour, materials; Metered connections, Distribution pipe length, System water loss	Volume of Water produced	26 rural Nevada water utilities	Privately owned utilities are most efficient; self-governing water districts are the least efficient. Municipal governments operate the most & least efficient utilities.	California	Bhattacharyya et al., 1995
2	**Stochastic frontier analysis (cost function)**	Total cubic meters of water distributed per year, total km of the water distribution system, average price of labour, average loss of water in the distribution, technology adopted in the water system	Variable cost includes direct costs & labour Costs	32 water distribution firms .	Efficiency losses if individual customers were served by more than one water distribution company. Two companies with adjacent water distribution systems will not allow a decrease in the average distribution costs.	Italy	Antonioli & Filippini (2001)
3	**Stochastic frontier analysis (cost function)**	Average salary, number of clients, daily production, number of connections, population density in area served, percentage of surface sources, number of hours per day, percentage of metered connections, qualitative treatment variables (chlorination, desalination)	Operational costs	50 water companies	Efficiency is not significantly different in private companies than in public sector utilities.	Asian & Pacific region countries	Estache & Rossi (2002)
4	**Stochastic frontier analysis (cost function)**	Water delivered, price of labour & capital. Explanatory, length of mains, average pumping head, proportion of river sources on total water sources, population density, volume of water introduced into the distribution system	Operational expenditure	10 water & sewerage companies, 12 water-only companies	Operating costs inefficiency has decreased over time with inefficiency differential between firms narrowing. Technical & structural requirements impact on cost efficiency	England & Wales	Bottasso & Conti (2003)
5	**Malmquist productivity Index**	Total staff, non-revenue water, Main lengths	Revenue water, Water customers	15 water & sewage utilities.	Productivity growth is negative over time period & Total factor productivity has negative value	Portugal	Marques & Monteiro (2003) - Model 1

No	Technique used	Independent Variable	Dependent Variable	Sample units considered	Outcomes	Country	Source
6	**Malmquist productivity Index**	Labour cost, depreciation, net assets return, Other OPEX	Revenue water, Water customers, Main length	15 water & sewage utilities.	Productivity growth is negative over time period & Total factor productivity has negative value	Portugal	Marques & Monteiro (2003) - Model 2
7	**Data envelopment analysis (cost function)**	Labour expenses, Operational costs, Other operational costs	Water produced, treated sewerage, population served-water, population served-treated sewage.	20 water & sewerage utilities,	Quantifies the relative efficiencies of state water & sewage companies. Network densities & water loss ratio influence efficiency. Exogenous variables had significant influence on efficiency	Brazil	Tupper & Resende (2004)
8	**Stochastic frontier analysis(cost function)**	Network length, number of employees, population served, ratio of population to network length, labour, electricity, materials, services & capital costs	Total costs.	18 territorial regions,	On average - inefficiency scores about 28%, partially explained by network characteristics.	Italy,	Fraquelli & Moiso (2005)
9	**Stochastic frontier analysis (production function)**	length of the piped network, number of employees	Water volume in m3/year	148 water firms	Private companies are only marginally more efficient than public ones. Technical efficiency estimated for the private sector is about 88% against 72% for the public sector	Brazil	Faria, Souza & Moreira (2005).
10	**Stochastic frontier analysis & data envelopment analysis(cost function)**	Operating & maintenance expenditure, Labour price, material price of water distributed, number of water treatment works	Water delivered, hours of piped water per day.	110 public & private water utilities,	Better performance in private utilities compared to state-owned utilities.	Africa	Kirkpatrick, Parker & Zhang (2006)
11	**Data envelopment analysis,& Malmquist indices**	Operating & capital expenditure	Number of properties connected, volume of water delivered.	18 water services businesses	Over the period 1995–2003, TFP fell by 1.2 per cent comprising an efficiency improvement of 1.1 per cent & a technological loss of 2.2 per cent	Australia	Coelli & Walding (2006)

No	Technique used	Independent Variable	Dependent Variable	Sample units considered	Outcomes	Country	Source
12	**Data envelopment analysis & stochastic frontier analysis (cost function)**	Labour, other operating expenditures & capital cost	Volume of delivered potable plus non potable water, number of household & non-household water connections, number of household & non-household sewerage connections, water losses, water population density, sewerage population density, time trend, regulatory change dummies.	10 water & sewerage companies	With price review, regulatory changes promoted reduction in technical inefficiency & bring inputs closer to their cost-minimizing levels from both a technical & allocative perspective.	England & Wales	Erbetta & Cave (2007)
13	**Stochastic frontier analysis (cost function)**	Price of labour, Price of capital, Price of material, Number of customers, Size of service area. Treatment dummy, dummies for surface water, underground water & low water losses	Total annual cos	52 water supply utilities	Need significantly decrease costs in order to become efficient. Inefficiency estimates depends on econometric specification. Diseconomies of scale in large utilities	Slovenia	Filippini, Hrovatin, & Zorić (2008)
14	**Data envelopment analysis (cost function)**	Delivery network, sewer network , labour & operational costs	Population Served, water delivered, collects sewage & treated sewage.	38 water utilities	Quantity-based technical efficiency is 71.3%. Quality dimension affect efficiency.	Spain	Picazo-Tadeo, Sáez-Fernández, & González-Gómez. (2008)
15	**Data envelopment analysis & stochastic frontier analysis (cost function)**	Client complaints, water main breaks, residential water clients, uncounted water & water source	Water client, Average salary, Price index from other index	127 Water & Sewerage firms	Different methodologies offer contradictory results for efficiency.	Latin America	Romero & Ferro (2008)

No	Technique used	Independent Variable	Dependent Variable	Sample units considered	Outcomes	Country	Source
16	**Data envelopment analysis & stochastic frontier analysis**	Operating costs, water loss, & the number of water connections.	Volume of water billed, the number of customers, coverage of service, & continuity of service	44 Water utilities	Consistency of the efficiency measurement is high. SFA techniques yield lower efficiency scores than does DEA	Peru	Berg & Lin (2008).
17	**Data envelopment analysis (cost function)**	labour, total workers & network length	Water billed, population served & number of connections	6 countries in Central	All companies are more productive from the view point of number of connections compared with volume of water billed. The comparison of performance of 6 countries is different due to different techniques	Central America	Corton & Berg (2009) (Model 1)
18	**Stochastic frontier analysis (cost function)**	number of connections	Operational, administrative expenses	6 countries in Central America	All companies are more productive from the view point of number of connections compared with volume of water billed. The comparison of performance of 6 countries is different due to different techniques	Central America	Corton & Berg (2009) (Model 2)
19	**Stochastic production frontier (production function)**	Staff & connections, Length of the piped network (Km), Installed production capacity (MLD), Density of customers (population „000/ Area in Km2), % Unaccounted for water (loss)	Average daily clear water production	18 urban cities	08 urban cities out of 18 performed better & scored highest estimated efficiencies. Mean technical efficiency is 84.47%.	India	Vishwakarma, & Kulshrestha, (2010)
20	**Data Envelopment Analysis (DEA)**	Operating expenditure, network length, non-revenue water	Volume of water delivered, number of connections & size of service area	11 state Water Supply Authorities & the 6 privatized water companies.	The private sector has an average overall technical efficiency score of 86% while the public sectors efficiency score is 70%. There is no evidence that private ownership is more successful then public ownership as there are also technically efficient public operated water supply entities	Malaysia	Munisamy (2010)

No	Technique used	Independent Variable	Dependent Variable	Sample units considered	Outcomes	Country	Source
21	**Data envelopment analysis**	Total revenue, Non-discretionary inputs: Length of network, leak ratio, groundwater ratio, elevation differences	Number of water meters, water delivered to households & non-households (industrial & other), network length, population	373 water utilities,	mean efficiency East Germany is 0.6574 while West Germany mean efficiency 0.6434 Network density & share of groundwater negatively influence efficiency	Germany,	Guder, Kittlaus, Moll, Walter &Zschille (2010)
22	**Data Envelopment Analysis & Stochastic Frontier Analysis**	Capital expenses & operational expenses	Delivered water volume & number of customers & water losses	73 water utilities,	Non-oriented model indicated that on average, decrease inputs by 4.1% & increase their desired outputs by 4.1% efficiently.	Portugal	De Witte & Marques (2010)
23	**Stochastic frontier analysis(cost function)**	Water delivery volume, Transmission pipe length, Capital price, Labour price, Network density, Supply population	Total cost	831 water utilities	Average inefficiency is approximately 37%. Small utilities are found to have higher output densities & scale economies than large ones.	Japan	Horn & Saito 2011
24	**Data Envelopment Analysis (DEA)**	capital cost, staff cost, & other operational experiences Volume of water billed) & the number of customers 14 exogenous variables included		1144 utilities	There is no influence on the efficiency of the Japanese water utilities during the period of study.	Japan	Marques, Berg & Shinji (2011)
25	**Data envelopment analysis (DEA) & Stochastic Frontier Analysis(cost function**	Water meters, Water delivered to households, Water delivered to non-households, output density, Population, share of groundwater input per utility structural variable: Network length, Output density, Leak ratio, Groundwater ratio, Elevation difference, Debt per capita	Revenues	373 public & private water utilities	Groundwater input & High price changes positively impact on efficiency. Under DEA analysis concluded that private governance mode shows less efficiency than publicly managed utilities. Efficiency levels under SFA were substantially higher than under DEA. The mean & median SFA efficiency scores are significantly higher than the DEA efficiency scores.	Germany	Zschillea & Walter (2012)

No	Technique used	Independent Variable	Dependent Variable	Sample units considered	Outcomes	Country	Source
26	**Multifactor productivity (MFP)**	capital & labour	The quantity of urban water sold to final customers; the number of sewerage connections; & the quantity of water supplied for irrigation	16 major urban water authorities	Industry gross value added for water services. MFP is negative for MFP growth phase & for full period.	Australia	Topp & Kulys (2012)
27	**Data envelopment analysis**	Network length, Employees	Water Connections, Final water deliveries, Bulk water supplies, Water produced	364 water utilities	Mean efficiency is 58.77%. There are substantial inefficiencies in the German water sector. While mergers can contribute to a reduction of those inefficiencies	Germany	Zschille (2012)
28	**Data envelopment analysis & Stochastic frontier analysis (cost function)**	capital, labour, &, materials	livestock, crops, other outputs	11 states in the northeastern	SFA models almost always true than DEA model for efficiency estimates. Different estimators showed different estimates for efficiency.	United States	O'Donnell, (2014)

As described in Table 2.5 previous studies have found different approaches to address the role of efficiency and performance measures for public and private water utilities. Out of these different approaches, three are significant: Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA) and Index approach. Some studies have applied the above approaches to determine whether private or public services are more efficient. For example, Bhattacharyya et al., (1995) found that privately owned utilities are the most efficient while self-governing water districts are the least efficient. Estache & Rossi (2002) concluded that efficiency of water utilities in Asian and Pacific region countries is not significantly different in private companies than in public sector utilities. Faria, Souza & Moreira (2005) demonstrated that private companies are only marginally more efficient than public ones.

However, a recent study on water utilities in Africa by Kirkpatrick, Parker and Zhang (2006), comparing privatized firms with non-privatized firms, found that there was no clear evidence that privatization did lead necessarily to higher performance than state owned utilities. More recently, Zschille & Walter (2012) demonstrate that privately governed water utilities show higher input slacks compared to publicly managed utilities because of greater revenues attained by privately organized water utilities in Germany. Further, Munisamy (2010) argued that efficiency scores do not depend on the type of ownership as there are also technically efficient public operated water supply entities in Malaysia.

As shown in Table 2.5, a number of different types of utilities measured technical efficiency using frontier efficiency measurement techniques (Stochastic Frontier Analysis (SFA) in different studies such as: Faria, Souza & Moreira (2005) and they found that the average technical efficiency estimated for the private sector is about 88% against 72% for the public sector in Brazil. Bottasso and Conti (2003) analysed English and Welsh water industries and found that inefficiency differentials among firms have steadily narrowed. Fraquelli and Moiso (2005) estimated a cost function for a sample of Italian multi-utilities providing gas, water and electricity, and found economies of scope to exist only for smaller utilities while cost advantages of diversification could not be confirmed for utilities larger than the median output level. On average, inefficiency scores are about 28%. Filippini, Hrovatin, & Zorić (2008) argued that Slovenian large water distribution utilities exhibited diseconomies of scale while small water utilities show scale economies (1.09). In Japan, Horn & Saito (2011) estimated cost inefficiency to be approximately 37%. Small water utilities are found to have higher output densities and scale economies than large ones. Antonioli and Filippini (2001) evaluated 32 Italian water utilities from 1991 to 1995 and compared the actual variable costs of the companies against a benchmark performance. This study concluded that efficiency losses if individual customers were served by more than one water distribution company. Two companies with adjacent water distribution systems will not allow a decrease in the average distribution costs. Recently, Vishwakarma & Kulshrestha (2010) estimated the mean technical efficiency as 84.47% using data from urban water utility for selected 18 urban cities of Madhya Pradesh, India.

On the other hand, Guder et al. (2010) considered technical efficiency scores of water utilities in Germany, based on cross sectional data from 373 water utilities in 2006 using Data Envelopment Analysis (DEA) method. According to the analysis, the mean efficiency score for water utilities operating in East Germany is 0.6574 while for West Germany the mean efficiency level was 0.6434. In addition to the above analysis, there are ample examples summarized in Table 2.5 which had used DEA methodology to analyse efficiency of water utilities such as, study by Malaysis, Munisamy (2010) which concluded that private sector has an average overall technical efficiency score of 86% while the public sectors efficiency score is 70%. Further, in Spain, Picazo-Tadeo, Sáez-Fernández, and González-Gómez (2008) measured quantity-based conventional mean technical efficiency as 71.3%. The quality-adjusted scores of technical efficiency for models 1 and 2 are 84.6 and 88.9 per cent respectively when variables of quality are omitted. This means that quality dimension affects efficiency. In Germany, Zschille (2012) estimated efficiency level as 58.77%. There are substantial inefficiencies in the German water sector. Tupper & Resende (2004) studied the relative technical efficiencies of 20 state water and sewage companies in Brazil during the 1996–2000 periods. By means of the flexible approach of DEA, this study concluded that network density affects efficiency and water loss ratio influences efficiency. Marques, Berg & Shinji (2011) applied DEA non-parametric technique to 5,538 observations on 1144 utilities in Japan that supplied drinking water between 2004 and 2007. According to this analysis, the study concluded that there is no influence on the efficiency of the Japanese water utilities during the period of study. De Witte & Marques (2010) estimated non-oriented conditional inefficiency using a sample which consists of 73 water utilities in Portugal during year 2005. The estimated inefficiency, on average, was 4.1 %, which indicates that the observations could simultaneously increase the inputs and decrease the outputs by 4.1 %.

Out of the studies which have been discussed above, few studies utilized both Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) to rank relative performance of water utilities worldwide. For example, Erbetta & Cave (2007) used DEA and SFA to measure the efficiency of 10 water and sewerage companies in England and Wales from 1993 to 2005. This study concluded that regulatory changes promoted reduction in technical inefficiency. The mixed methodologies offer contradictory results. For example, Romero & Ferro (2008) conducted a study using 127 Latin American water and sewage firms for the period of 2003 to 2005. Further, Berg & Lin (2008) examined the performance patterns to compare firm efficiency using data from 44 water utilities in Peru during the period of 1999 to 2006. Corton & Berg (2009) examined data across 6 countries in Central America, focusing on three core indicators: operational performance, cost, and quality during 2002 to 2005. In contrast to the above studies, this study concluded that the comparisons of performances are different for different methodologies such as DEA and SFA. On the other hand, Zschille and Walter (2012) estimated technical efficiency scores based on cross-sectional data from 373 public and private water utilities in Germany's water supply industry in 2006 and revealed that the mean technical efficiency under SFA is significantly higher than the DEA efficiency scores. Further, most recently, O'Donnell (2014) estimated efficiency and productivity change for 11 states in the North Eastern United States for 30 years from 1960 to 1989. These studies concluded that the estimated efficiency under SFA is significantly higher than under DEA. Further, these studies concluded that the different estimators showed different estimates.

In addition to above approaches, the measures of efficiency obtained from these studies have varied widely with significant variability. For example, Coelli and Walding (2006) employed the Malmquist index approach to analyse efficiency and productivity measurement of Australian water utilities. Over the period 1995–2003, total factor productivity fell by 1.2 per cent, comprising an efficiency improvement of 1.1 per cent and a technological loss of 2.2 per cent. Further, Marques & Monteiro (2003) used the same Malmquist index approach to analyse efficiency and productivity measurement of Portuguese water utilities over a period of 8 years. This study concluded that total factor productivity has a negative value in Portuguese water utilities. On the other hand, Topp & Kulys (2012) used Multifactor Productivity (MFP) trends approach, to demonstrate the driving forces comparing long periods (1974-75 to 2009-10) in Australia, in order to better understand some of the longer-term issues that impact on MFP trends and developments in the utilities division.

2.5. Input-Output Variables for Performance Measures in Water Utilities

In order to measure (analyse performance) efficiency and productivity in water utilities, previous studies have followed a production approach with different specifications in defining the input-output relationships. The production approach views water utilities as producers of physical water outputs which include clear water production (Vishwakarma & Kulshrestha, 2010; Zschille, 2012) or the volume of water delivered (De Witte & Marques, 2010; Horn & Saito, 2011). In this study, specification of input and output data is considered to water-only, to avoid misspecification of input-output data. Table 2.6 provides details of input and output data which are used in different studies. Data for cost frontiers under parametric approach depends on cost input/output data. DEA and production cost frontiers estimate economic efficiency with the use of cost input/output data. For production frontier under parametric approach, only data on quantities is used. Production frontier technical efficiency, which is described with input/output data lie on quantities only.

However, the specifications of outputs are presented with the proportion of water delivered to households and/or non-households through water connections, volume of water distributed and the length of distribution mains. These factors are considered as common output data in the network industries in water utilities as per past studies. In additions to above outputs, the specifications of output measures used across studies indicate a significant geographical element, as population density is varied from one geographical location to another. This is calculated by dividing the number of properties served or the population by the network length by customers.

Further, the users may require drinking water of a higher quality. The utility may seek to maximise some output service quality for the efficiency measurement process, as this likely reflects flexible actions taken by management. Previous studies have identified the situation which is important to increase efficiency and have included the specifications of output measures. Especially, the average pumping head of water main, relevant to the length of mains and/or the elevation, number of hours of supply per day, and/or number of water metres and/or water losses. In addition to above specifications of output measures in past studies, there is obviously a substantial variation of outputs across studies such as the number of water connections and/or metred connections.

Table 2.6: The specification of input and output data

No	Independent variable (input)	Source	Dependent variable (output)	Source
1	Variable costs / Operational cost/Expenditure/ capital cost	Tupper and Resende (2004), Fraquelli and Moiso (2005), Kirkpatrick, Parker and Zhang (2006), Coelli and Walding (2006), Erbetta& Cave (2007), Picazo-Tadeo, Sáez-Fernández, and González-Gómez. (2008), Berg & Lin (2008), Munisamy (2010), De Witte & Marques (2010), Marques, Berg & Shinji (2011), Topp & Kulys (2012), O'Donnell, (2014)	Variable costs / Operational cost/ Expenditure/ capital cost	Antonioli & Filippini (2001), Estache& Rossi (2002), Bottasso and Conti (2003), , Fraquelli and Moiso (2005), Filippini, Hrovatin, & Zorić (2008), Corton& Berg (2009), Horn & Saito 2011
2	Energy cost	Bhattacharyya et al., 1995, Fraquelli and Moiso (2005)		
3	Total Cost		Total Cost	Fraquelli and Moiso (2005)
4	Technology Adopted	Antonioli & Filippini (2001)		
5	Production capacity	Vishwakarma, & Kulshrestha, (2010)		
6	Labour cost	Bhattacharyya et al., 1995, Antonioli & Filippini (2001), Bottasso and Conti (2003)Tupper and Resende (2004),Fraquelli and Moiso (2005), Kirkpatrick, Parker and Zhang (2006), Filippini, Hrovatin, & Zorić (2008), Picazo-Tadeo, Sáez-Fernández, and González-Gómez (2008), Horn & Saito 2011, Topp & Kulys (2012), O'Donnell, (2014)	Labour cost	Tupper and Resende (2004)
7	Cost of materials	Bhattacharyya et al., (1995), Fraquelli and Moiso (2005), Kirkpatrick, Parker and Zhang (2006), Filippini, Hrovatin, &Zorić (2008), O'Donnell, (2014)		

No	Independent variable (input)	Source	Dependent variable (output)	Source
8	Ground water ratio	Zschillea and Walter (2012)		
9	Client complaints	Romero & Ferro (2008)		
10	Water main breaks	Romero & Ferro (2008)		
11	Volume of Water produced	Antonioli&Filippini (2001)	Volume of Water produced	Bhattacharyya et al., (1995), Tupper and Resende (2004), Faria, Souza & Moreira (2005), Vishwakarma, & Kulshrestha, (2010), Zschille (2012)
12	Metered connections,	Bhattacharyya, (1995), Estache & Rossi (2002)		
13	Leak ratio	Zschillea and Walter (2012)		
14	Quality of water	Estache & Rossi (2002)		
15	Percentage of surface water	Estache & Rossi (2002)		
16	Number of employees	Fraquelli and Moiso (2005), Zschille (2012)		
17	Distribution pipe length / Network length	Bhattacharyya et al., (1995), Bottasso and Conti (2003), Marques & Monteiro (2003), Fraquelli and Moiso (2005), Fraquelli and Moiso (2005),Faria, Souza & Moreira (2005), Picazo-Tadeo, Sáez-Fernández, and González-Gómez. (2008), Corton& Berg (2009), Vishwakarma, & Kulshrestha (2010), Munisamy (2010), Guder, Kittlaus, Moll, Walter and Zschille (2010), Horn & Saito 2011, Zschillea and Walter (2012), Zschille (2012),	Distribution pipe length / Network length	Guder, Kittlaus, Moll, Walter and Zschille (2010)

No	Independent variable (input)	Source	Dependent variable (output)	Source
18	Water loss	Bhattacharyya et al., (1995), Antonioli & Filippini (2001), Erbetta& Cave (2007), Filippini, Hrovatin, &Zorić (2008), Berg & Lin (2008), Marques, Berg & Shinji (2011), Zschille (2012)	Water loss	De Witte & Marques (2010)
19	Volume of water distributed	Antonioli & Filippini (2001), Bottasso and Conti (2003), Coelli and Walding (2006), Horn & Saito 2011, Horn & Saito 2011, Marques, Berg & Shinji (2011), Topp & Kulys (2012)	Volume of water distributed	Marques & Monteiro (2003), Kirkpatrick, Parker and Zhang (2006), Erbetta & Cave (2007), Picazo-Tadeo, Sáez-Fernández, and González-Gómez. (2008), Berg & Lin (2008), Corton & Berg (2009).
20	Number of connections	Estache & Rossi (2002), Coelli and Walding (2006), Filippini, Hrovatin, &Zorić (2008), Romero & Ferro (2008), Berg & Lin (2008), Marques, Berg & Shinji (2011), Zschillea and Walter (2012), Zschillea and Walter (2012)	Number of connections	Marques & Monteiro (2003), Erbetta& Cave (2007), Romero & Ferro (2008), Berg & Lin (2008), Corton& Berg (2009),Munisamy (2010), Guder, Kittlaus, Moll, Walter and Zschille (2010), De Witte & Marques (2010), Zschille (2012)
21	Population density	Estache & Rossi (2002), Bottasso and Conti (2003), Tupper and Resende (2004),Fraquelli and Moiso (2005), Erbetta & Cave (2007), Vishwakarma, & Kulshrestha, (2010), Horn & Saito 2011, Marques, Berg & Shinji (2011), Zschillea and Walter (2012)	Population density	Tupper and Resende (2004), Picazo-Tadeo, Sáez-Fernández, and González-Gómez. (2008), Corton& Berg (2009), Guder, Kittlaus, Moll, Walter and Zschille (2010)
22	Number of hours water available per day	Estache & Rossi (2002)	Number of hours water available per day	Kirkpatrick, Parker and Zhang (2006)

No	Independent variable (input)	Source	Dependent variable (output)	Source
23	Average pumping head/ elevation	Bottasso and Conti (2003), Zschillea and Walter (2012)	Average pumping head/ elevation	Guder, Kittlaus, Moll, Walter and Zschille (2010)
24	Number of staff	Marques & Monteiro (2003), Faria, Souza & Moreira (2005), Corton& Berg (2009), Vishwakarma, & Kulshrestha, (2010)		
25	NRW	Marques & Monteiro (2003), Romero & Ferro (2008), Vishwakarma, & Kulshrestha, (2010), Munisamy (2010)		
26	Treated Sewerage volume/ connections	Erbetta & Cave (2007)	Treated Sewerage volume/ connections	Tupper and Resende (2004),Erbetta& Cave (2007) , Picazo-Tadeo, Sáez-Fernández, and González-Gómez (2008), Topp&Kulys
27	Size of service area	Filippini, Hrovatin & Zorić (2008)	Size of service area	Berg & Lin (2008), Munisamy (2010)
28	Total revenue	Guder, Kittlaus, Moll Walter and Zschille (2010)	Total revenue	Zschillea and Walter (2012)
29	Number of water metres	Zschillea and Walter (2012)	Number of water metres	Guder, Kittlaus, Moll, Walter and Zschille (2010)
30	Volume of water supplied for irrigation		Volume of water supplied for irrigation	Topp&Kulys (2012)
31	Output Density	Zschillea and Walter (2012) Zschillea(2012)		
32	Average salary	Estache & Rossi (2002)		
33	Number of Clients	Estache & Rossi (2002)		

Turning now to inputs, total revenues which is treated as the proxy for total costs, is considered as a reasonable single input variable. On the other hand, some studies have restricted themselves to a single input in the form of operational expenditure while total cost is taken as a single input. Instead of arguing on single input, there are some attempts to divide expenditure more finely into operating and capital costs; capital and labour cost and other operational costs; or even capital, labour, land and material cost.

Slightly confusing, a number of studies specify variables as inputs that elsewhere serve as outputs. For example, Munisamy (2010) include length of pipe network as inputs in his study of Malaysian water network while Guder et al., (2010) specify the length of pipe network as outputs in Germany's water supply industry. This means, inputs and outputs are beyond the direct control of management (e.g. water quality standards and environmental and structural factors) or during the sample period. Some studies specify inputs as the amounts of labour, energy, materials, used number of staff and average salary. According to Table 2.5, it is clear that there is no consensus on variables, which are used as inputs and outputs because variables which are used as inputs are used elsewhere as outputs. There are 31 inputs out of 36 variables used as input data in past studies.

2.6. Summary

The literature review provides the background information for this research by critically reviewing previous studies which have focused on efficiency and productivity measurement of water utility sector published since 1995. Of the 28 past studies in Table 2.5, 40 % are based on urban water utilities in Western Europe, 30 % in the United States and the remainder, are on water utilities from Japan, India, Malaysia, Australia, Asia and Africa.

This chapter provides useful insights into efficiency in urban water utility sector. Most of past studies compare the efficiency with public water utilities verses private water utilities. These studies affirm that efficiency is not significantly different in private water utilities than public water utilities. Further, some studies revealed that SFA models almost always are truer than DEA models for efficiency estimates.

The data available from past studies is basically categorized as discretionary and non-discretionary data. The discretionary data are due to physical environmental factors and/or organizational, managerial and regulatory policy. Non-discretionary data from the socio-economic profile and topography of a water utility is beyond firm's control.

One difficulty which had been identified in relation to previous research on efficiency studies is, mixing of utilities from different contexts. This creates a problem in specifying a set of input and output data. Further, the input data, especially, are often poorly available. The identification of input data which includes independent variables, controllable variables and uncontrollable variables, is one of the major tasks. As mentioned in section 2.5, the underlying assumptions of the main efficiency techniques vary markedly and are very sensitive to variable specification.

As a result, future researchers need to address the issue of realistic and valuable inputs/outputs, agreeable to managerial control, including levels of customer satisfaction, water quality, the prevention of loss of supply, and so on. With rigorous comparison of techniques, the outcomes may be accepted by regulators, utilities, the public at large, and other stakeholders, concerned with achieving efficient, reliable and sustainable urban water supplies in the 21st century.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. Introduction

The purpose of this chapter is to review the best fit methodologies on efficiency measurement techniques in water utilities and screen the best industry practiced technique for this study. With the aid of past studies, the methodological approaches which evaluate performance of water utilities are simply discussed here. Then, the best fit efficiency measurement technique is sieved and developed as the efficiency estimation model for NWSDB to estimate efficiency. Finally, the selection of best fit efficiency model for NWSDB is described in this chapter below.

This chapter comprises four sections. Section 3.2 briefly discusses the selection of efficiency measurement approach used in past studies. This section has four sub sections. Section 3.3 examines specification of methodology for NWSDB including two sub sections. Section 3.4 provides some concluding remarks.

3.2. The Possible Approaches to Efficiency Measurement in Water Utilities

In reality, the producers are not always efficient. In this context, the analysis of efficiency is a practice which offers valuable information to the management with a control mechanism to monitor the performance of production under its control and to the regulatory bodies (Fried et al., 2008). Further to Fried et al. (2008), generally, the water utilities as a producer of drinking water produce and supply treated water using various inputs such as labour, capital, chemicals, energy, technology and so on. Then, water utilities use different approaches to measure efficiency and performances calculations in production environments. This section concentrates on a frontier approach applied on selected efficiency and performances studies of urban water utilities in the past, based on section 2.4.

To estimate the efficiency, it is very necessary to know the true function of the process of the industry (Kumbhakar and Lovell, 2000). If theoretically defined functional model based on engineering knowledge of the process of the industry is unknown, the relevant actual functional model based on the observed data must be constructed (Kumbhakar and Lovell, 2000; Fried et al., 2008). As water utilities follow the production process, the construction of frontier functional model for the production process, using the best currently known production techniques is the first step to evaluate the efficiency of actual organisations and industries. To overcome the above issue, frontier models have been developed over four decades to estimate efficiency in water utilities and other sectors. In this context, the most applied and possible two choices of principal approaches to construct the frontier for water utilities are:

1. Non-parametric approach (Data Envelop Approach-DEA).
2. Parametric Approach (Stochastic Frontier Approach-SFA).

The past applications of the above approaches cover a range of services including water, healthcare, financial, education, fishing industry, air transport, electricity and gas generation/distribution, and are currently used in many fields (Fried et al., 2008). In order to measure efficiency in water utilities, Table 2.5 in section 2.4 shows empirical literature regarding the possible approaches used in water utility.

As aforementioned, this section comprises of four sub sections. Section 3.2.1 demonstrates the sequence of building the frontiers. Section 3.2.2 discusses Non-parametric Approach. Section 3.2.3 demonstrates Parametric Approach using cost function and is followed by section 3.2.4 which discuses Parametric Approach using production functions.

3.2.1. The flow of construction sequence of frontier functions

The major challenge in water utilities is to construct the frontier functional model to estimate efficiency because true function is unknown. To construct the frontier functional model, possible choices of frontier applications that have been applied for the most part, and have been published in past literature, can be summarized as shown in Figure 3.1.

The possible approaches to construct Frontier Model to estimate efficiency in past literatures for water utilities

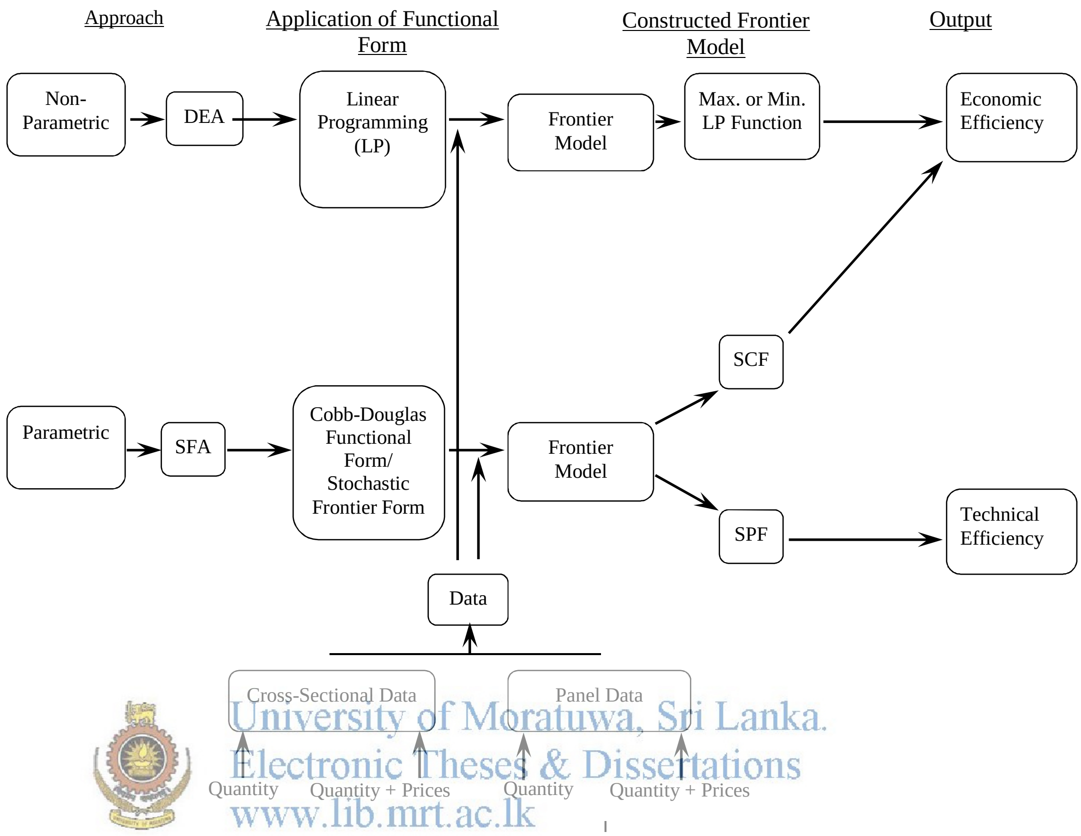


Figure 3. 2: Possible Choices of Frontier applications in Water Utilities

(Source: Hargreaves et al., 2010).

DEA – Data Envelop Approach, SFA - Stochastic Frontier Approach,

SCF - Stochastic Cost Frontiers SPF Stochastic Production Frontiers

3.2.2. Non-parametric approach

Non-parametric approach is a convenient approach to estimate efficiency of observational data in water utilities (Greene, 2008). Further, Non-parametric approach denoted as DEA involves mathematical programming approach to construct linear programming (LP) problem over the observed data to measure efficiency. The observed data set is subject to certain assumptions and envelops the data set through LP method. LP method does not require specification of a functional form or a distributional form. The LP problem will be profit or revenue maximizing problem or cost-minimizing problem. DEA model makes cost models and provides a flexible framework for economic efficiency (Fried et al., 2008; Greene, 2008). An important point is that the mathematical programming approach strictly involves 'measurement' or 'calculation'. DEA model is a function of multiple outputs and inputs. Further, DEA does not include a random error term, or accommodation for noise.

The type of observed data can be divided into quantities or quantities and prices (Fried et al., 2008). Depending on the data set, the frontier can be categorized in terms of production frontier (production function) as well as an economic frontier (cost function, profit function, revenue function) for water utilities. Using the constructed frontier, efficiency can be categorized as technical efficiency and economic efficiency.

According to the types of variable data which is inclusive of quantities and prices, economic efficiency can be estimated and categorized into technical efficiency and allocative efficiency. DEA model with a cross sectional data observes each producer's performance once. DEA, having a panel of data consisting of T time periods, observes each producer over a period. Trends in efficiency, estimates individual producer and may be separate frontiers for each period have to be used. The above non-parametric approach had been applied for urban water utilities worldwide. Chapter 2 discussed the examples for DEA in past literatures.

3.2.3. Parametric approach- Stochastic Cost Frontiers (SCF)

This section presents an overview of techniques for parametric analysis of technical (production) and economic (cost) efficiency. The parametric approach denoted as Stochastic Frontier Approach (SFA) is represented as analytical approach (Bhattacharyya et al., 1995; Kumbhakar and Lovell, 2000). In contrast to the DEA, the aim of parametric approach is to construct frontier functional models based on theory-based production, cost and profit frontier functional models to estimate technical and economic efficiency of a producer (Kumbhakar and Lovell, 2000; Greene, 2008). As mentioned in section 3.2, the construction of frontier functional model is a challenge because true frontier functional model in production environment is unknown under parametric approach in real industry as well (Kumbhakar and Lovell, 2000). This means that frontier functional model must be estimated using sample data. Recent studies have demonstrated that frontiers are typically classified as stochastic cost frontiers and stochastic production frontiers in order to estimate efficiency in parametric analysis (Bhattacharyya et al., 1995 and Fried et al., 2008). This widely used stochastic frontier removes some of the limitations of the earlier stochastic frontier models and introduces a disturbance term representing noise, measurement error and shocks beyond control, related to the water producers (Bettese and Coelli, 1992 and Greene, 2008).

The variable data for stochastic frontier model lies on quantities only or quantities and price data (Greene, 2008). The variable data set for frontier model is bound by Stochastic Frontier (Bettese and Coelli, 1992; Fried et al., 2008). An important understated terminological distinction is that the stochastic frontier approach comprises 'estimation' of the efficiency rather than measure or calculation (Fried et al., 2008 and Greene, 2008).

As mentioned earlier (Table 2.5), the models of stochastic cost frontiers treat economic efficiency (Bhattacharyya et al., 1995; Zschillea and Walter, 2012). This cost frontier may be a function of multiple outputs, inputs and input prices. Typically, multiple outputs in water utility efficiency analysis are cost frontiers or revenue frontiers. The estimation of cost function requires the specification of a functional form (Fried et al., 2008 and Greene, 2008). Cobb-Douglas functional form offers an appropriate functional form with the conversion to the translog form (Bhattacharyya et al., 1995; Fried et al., 2008 and Greene, 2008). Table 2.5 in chapter 2 presented the examples used in past literature for stochastic cost frontier functions, to estimate economic efficiency in water utilities. All deviations are attributed to overall cost inefficiency.

To estimate economic inefficiency, the basic stochastic frontier cost functional model used in past studies revealed as equation (1):

(1) $C_i = \alpha_0 + \sum^{n}_{i=1} \alpha_i (x_i) + v_i + u_i$ $\qquad$ $i=1,2,3\ldots n$ sectors

Where, C_i denotes the costs, X_i stands for the vector of variables. The α is unknown parameters to be estimated known as elasticity. The v_i component captures the effects of the stochastic noise and is assumed to be independent and identically distributed following a normal distribution $v_i \sim N(0, \sigma_v^2)$. The $u_i \sim N(0, \sigma_u^2)$ component represents the cost inefficiency and is assumed to be distributed independently from v_i.

3.2.4. Parametric approach- Stochastic Production Frontiers (SPF)

In the production form, the stochastic production frontier approach (SPFA) is defined as an output, is a function of inputs (Bettese and Coelli, 1992; Fried et al., 2008 and Greene, 2008). In this form, it is difficult to incorporate multiple outputs. Only one single variable for output is utilized. Water utilities as producer of drinking water under the structure of the production frontier can be evaluated in terms of technical efficiency to demonstrate performance. Battese and Coelli (1992) who followed a model independently, proposed by Aigner, Lovell and Schmidt (1977), demonstrated that stochastic production frontier differs from the traditional (average) production function. It has two components: one to account for technical inefficiency and the other to permit random events (uncontrollable) that affect production.

However, the production function approach uses data with quantity only, to estimate technical efficiency due to the absence of good proxies especially for capital price (Greene, 2008 and Fried et al., 2008). As described in Table 2.5 in Chapter 2, examples for production frontier function in an environment defined by a stochastic production frontier functional model in water utilities to estimate technical efficiency in water utilities are: Faria, Souza & Moreira (2005) and Vishwakarma & Kulshrestha (2010).

The above past two studies with SPFA is subjected to a statistical functional form called Cobb-Douglas production functional form, which transforms it into logarithmic form to estimate technical efficiency in water utilities. The above two studies clearly revealed that the Cobb-Douglas and its translog functional models overwhelmingly exhibit the applications in stochastic cost and production frontiers to estimate econometric or technical inefficiency estimations. As mentioned in chapter 3.2, Coelli (2008) demonstrated that Stochastic Frontier Approaches (SFA) have been developed over 40 years to estimate technical inefficiency and economic inefficiency in water utilities. The Stochastic Production Frontier was first proposed independently by Aigner, et al., 1977 and Meeusen & van den Broeck (1977) for multiple input variables.

The Cobb-Douglas functional form was developed and tested against statistical evidence by Charles Cobb and Paul Douglas during 1927-1947 (Samuelson, 1979). In economics, Cobb–Douglas production function is a particular functional form to construct production frontier which is widely used to represent the technological relationship between the amounts of two or more inputs. The Cobb-Douglas and its In developing countries, water utilities bear massive challenges, in supplying pipe-borne water. National Water Supply & Drainage Board (NWSDB), the sole supplier of safe drinking water in Sri Lanka, under the Ministry of City Planning & Water Supply, increased its piped water services to cover 34% of population in 2014. NWSDB's Corporate Planning Division presents its performance, showing access to safe drinking water, via Annual and Key Performance Indicator (KPI) Reports, using different ratios with eleven variables. Performance is imperative for the betterment of a water utility. Recognizing this fact, the study proposes an alternative way of presenting performance of NWSDB, because single ratios do not provide comprehensive explanations about performance of water utilities.

Therefore, this study focused on the productive efficiency concept under parametric approach to estimate technical efficiency using Stochastic Production Frontier (SPF) technique as the best Industry Practice. First, SPF model was proposed for NWSDB. Then, selected regional manager's centres producing pipe-borne water were analysed using SPF model, to check its inefficiency. The test statistics confirmed that SPF model was an inefficiency model. Finally, NWSDB was analysed using SPF model and overall mean technical inefficiency and technical efficiency were estimated for the period of 2010, 2011, 2012, 2013 and 2014. The SPF model was analysed using maximum likelihood iteration method to estimate the elasticity values of parameters, using the 'STATA' software package, specially designed for stochastic frontier models.

Study confirmed NWSDB manages a similar technical efficiency level annually. Technical efficiency trend showed the increase occurring at a diminishing rate. Finally, the inefficiency model derived from the SPF model was proposed to NWSDB, which clarified the significance of variables affecting NWSDB's production, directly or indirectly, to managers etc. This SPF model allowed NWSDB to estimate mean technical efficiency for presenting performance reports as an alternative. Translog models dominate the applications of literatures in stochastic frontier and econometric inefficiency estimation (Greene, 2008). It is obvious that Cobb-Douglas functional form (composed error model) as a basic functional model was used to construct the stochastic frontier to estimate technical and economic efficiency in past studies, because Cobb-Douglas functional form has developed with a two-sided error term which overwhelms the earlier frontier model with only one-sided disturbance to the model.

In addition to water sector, there were plenty of studies in the past that used stochastic frontier analysis approach, since stochastic production frontier functions are important for prediction of technical efficiencies of individual firms in an industry. For examples, Battese and Coelli (1992) used agricultural data to analyse paddy farmers in India; Son, Coelli & Fleming (1993) analysed data collected in natural rubber production in Vietnam. Further, Villano, Fleming, Farrell & Fleming (2006) analysed wool producers in Australian sheep industry using the SPF approach.

To estimate technical inefficiency of a firm, the well-known basic stochastic frontier production functional model in the past studies, used the following:

(2) $Y_i = \beta_0 + \sum^{n}_{i=1} \beta_i (X_i) + v_i - u_i$ i =1,2,3….n sectors

Where, Y_i is the clear water production of the i^{th} firm, X_i is a row vector of the input quantities of i^{th} firm and β is unknown parameters to be estimated known as elasticity. The functional form is having two error components which includes $v_i \sim N(0, \sigma_v^2)$ error term (Aigner et al., 1977 and Jondrow et al., 1982) and half-normal distribution of non-negative inefficiency term $u_i \sim N(0, \sigma_u^2)$ (Aigner et al., 1977 and Jondrow et al., 1982).

In order to separate the stochastic and inefficiency effects, u_i is introduced to the function. Here, u_i is independent of v_i under the control of firm. u_i represents inefficiency of a model. v_i is uncorrelated with X_i, an independent and identical variable. Past studies revealed that v_i which can't be controlled by the firm is considered due to luck, weather or measurement error and so on. SFA makes the assumption that the residual from the simple regression approach can be divided into two factors, statistical error and inefficiency. Inefficiency is assumed to be non-negative (a utility that has zero inefficiency is on the efficiency frontier) and follows a particular statistical distribution (for example, a half normal' distribution or truncated normal distribution).

3.3. The Specification of Methodology for NWSDB

The NWSDB as a main provider of safe drinking water in Sri Lanka, the main objective is to quench the country's water demand. To achieve the demand NWSDB has to produce drinking water with sufficient quality from a source (groundwater or surface water). In order to provide quality water to customers, a water production process is ensued with the following activities: (i) water extraction from groundwater or surface water (raw water) (ii) treatment of water, (iii) transfer of water through transmission pipelines, (iv) storage of water, (vi) pressurization of water pipelines, and (vii) finally distribution of water to customers through distribution mains which also includes quality monitoring and metering.

Being a publicly owned water utility, NWSDB is generally not allowed to maximize profits (Corporate Plans for NWSDB, 2012-2016; 2012). NWSDB is not a profit oriented organization like a private organization. In this context, NWSDB has to manage the whole pipe-borne water demand at regulated prices (Corporate Plans for NWSDB, 2012-2016; 2012). On the other hand, water tariff cannot be increased due to the government regulation. However, NWSDB has to provide services at a present tariff. As the principal water utility provider in Sri Lanka, NWSDB operates in a monopolistic nature. Therefore, there should be a systematic approach to assess the efficiency and performance of NWSDB to know the right way through which it can achieve its maximum output/service goals as mentioned earlier in section 2.2.

As NWSDB produces and supplies treated water using various resources, the economic structure of NWSDB can be analysed within the production theory framework. On one hand, NWSDB has to increase its performance with the aim of increasing production efficiency levels to cater for future demand while maintaining regulated prices. On the other hand, NWSDB has to produce more water efficiently by maintaining its input cost structure at the same level without increasing the prices. Within this constraint, behaviour of NWSDB would be consistent with econometric theory as decisions are made with respect to production form. Hence, according to past literature, estimation of efficiency through production function is 'technical efficiency'. Greene (2008) concluded that efficiency in terms of production is a measure of technical efficiency.

Therefore, NWSDB as a major water producer in Sri Lanka can be analysed using SPFA which is under parametric approach to estimate technical efficiency as described in section 3.2.4. The first step is to construct a production frontier function as "true function" is unknown. The "function" itself is a relationship between inputs and outputs which are based on the significant variables represented in the performance report of NWSDB. In this analysis, the functional form required to develop frontier function is Cobb-Douglas functional model and Stochastic Frontier functional model because Cobb-Douglas functional model has universally accepted economic theory to construct Stochastic Production Frontier (SPF (Greene, 2008).

To construct SPF, data is obtained for a particular period because data changes for different periods. Therefore, this study used monthly observational data over five years from 2010 to 2014.

The Stochastic Production Frontier (SPF) to NWSDB

As discussed above, the basic model selected for NWSDB is based on the stochastic production frontier function. Usually, the production model is linear of the variables (Greene, 2008). Aigner et al. (1977) referred Aigner and Chu's (1968) that frontier production functional model begins with reformulation of a Cobb-Douglas model. Now, the stochastic frontier model is the standard econometric platform for this type of analysis (Aigner et al., 1977). Further, Aigner et al. (1977) proposed a normal/half-normal model for SFA with a composed error term which includes noise term v_i and an inefficiency term u_i.

The straight forward stochastic production frontier function to the NWSDB is proposed following general functional form which had been developed by Aigner et al. (1977), Jondrow et al. (1982) and Greene (2008) followed by Aigner and Chu (1968) as equation (3):

(3) $y_i = \beta_0 + \sum^{n}_{i=1} \beta_i (x_i) + v_i - u_i = \beta_0 + \sum^{n}_{i=1} \beta_i (x_i) + \varepsilon_i$

$i = 1,2,3\ldots n$ Regions.

Where, Y_i is the clear water production of the i^{th} region, X_i is the input quantities of variables of i^{th} firm and β is unknown parameters to be estimated known as elasticity. The term ε_i represents the composed error (residual) with two independent components in equation (4) such as,

(4) $\varepsilon_i = v_i - u_i$ (Aigner et al., 1977; Jondrow et al., 1982; Greene, 2008 and Fried et al., 2008).

According to the above model, ε_i can be estimated by the shortfall of output (y_i) from its maximal possible value given by the stochastic frontier $\beta i \ln(x_i) + vi$ such as;

$\acute{\varepsilon}_i = y_i$ – (maximum possible value (Output) given by the stochastic frontier ($\acute{y}_i$) using maximum likelihood iteration method followed by "STATA" satirical Software)

This $\acute{\varepsilon}_i$ can be functioned as equation (5);

(5) $\acute{\varepsilon}_i = y_i - \acute{y}_i$

The above $\acute{\varepsilon}_i$ can be regarded as estimator of the error terms ε_i. Here, ε contains information about technical inefficiency term u_i. All deviations from this frontier are the assumed results of inefficiency. As before, term $u_i \sim N(0, \sigma_u^2)$ is a one-sided error term representing technical inefficiency. Term $v_i \sim N(0, \sigma_v^2)$ is a two-sided error term representing the usual statistical noise found in any relationship. The above terminology is suggested by Aigner et al. (1977), Jondrow et al. (1982) and Battese and Coelli (1992).

Technical Inefficiency Term (u_i)

The main objective of the above model is to separate term u_i which represents the technical inefficiency from the density function of ε_i. The straight forward density function of ε is given by eq. (8) of Aigner et al. (1977) as shown in equation (6),

(6) $f(\acute{\varepsilon}_i) = f^*\left(\frac{\varepsilon}{\sigma}\right)[1 - F^*(\varepsilon\lambda/\sigma)]$

Where $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\lambda = \sigma_u / \sigma_v$ and f^* and F^* is standard normal density and distributional functions respectively.

Here $f(\varepsilon)$ is considered as half-normal distribution (Aigner et al., 1977). If σ_v^2 is zero, $f(\varepsilon)$ becomes half-normal distribution with error term. The usual distributional function is as follows;

$$f(\varepsilon) = \begin{cases} \frac{\sqrt{2}}{\sqrt{\pi}}\sigma_u \exp(-\varepsilon^2 / 2\sigma_u^2) & \text{if } \varepsilon \geq 0 \\ 0 & \text{if } \varepsilon < 0 \end{cases}$$

The Expected Value of Technical Inefficiency- E(u)

The expected value E (ε) (the expected value of u_i) and variance of density function of f ($έ_i$) is shown in equation (7) and (8);

(7) $$E(\varepsilon) = E(u) = \{-\frac{\sqrt{2}}{\sqrt{\pi}}\sigma_u\}$$

(8) $$V(\varepsilon) = v(u) + v(v)$$
$$= \frac{\pi-2}{\pi}\sigma_u{}^2 + \sigma_v{}^2$$

Hence, the mean technical inefficiency can be estimated by using equation (7) ; one's estimate of σ_u. Or average technical inefficiency can be estimated by average of the έ (Aigner et al., 1977) and Jondrow et al., 1982).

Mean Technical Efficiency and Technical Inefficiency Function

The Technical Efficiency (TE_i) = exp(– u_i) (Greene, 2008)

However, the mean technical inefficiency can be represented as functional form with controllable variables in equation (9) such as;

(9) $\mu_i = \delta_o + \sum^{n}_{j=1} \delta \ln(X_j)$.

i =1,2,3….n sectors J=1,2,3….n variables

Where, δ is representing elasticity of inefficiency and X represents controllable variables for inefficiency function.

Four different distributional assumptions have been used in the past literature for specifying the one-sided error term *(a)* truncated-normal, *(b)* half-normal, *(c)* exponential, and *(d)* gamma (Greene (2008) and Parmeter & Kumbhakar (2014).

Application of Software Package – "STATA"

As mentioned, the half normal stochastic frontier model is easily programmed with most econometric computer software packages to estimate parameters which includes such as β, σ^2, σ_u^2, σ_v^2, and $\gamma = (\sigma_u^2) / \sigma^2$ values using maximum likelihood (ML) methods by an iterative maximization process (Greene, 2008). Past studies revealed that the most specialised software used in stochastic frontier model is such as 'STATA' and 'FRONTIER' software. Therefore, this study brings into light specialized frontier software such as 'STATA' software programme to estimate parameters.

Hypothesis

The term γ measures the relative magnitude of the variance associated with the inefficiency effects (Battese and Coelli, 1992; Greene, 2008 and Fried et al., 2008). If γ = 0, the frontier is due entirely to noise and remove inefficiency term u_i. It concludes that there are no inefficiency effects in the model. Therefore, the γ> 0 is indicating that all deviations are due to inefficiency. In this context, the testing hypothesis for the constructed frontier model for NWSDB is as follows;

H_0 = the constructed frontier model is fully efficient. There is no inefficiency effect in the model except that which is due entirely to noise.

H_1 = the constructed frontier model is not fully efficient.

The test statistic is presented in equation (10);

(10) $\gamma = (\sigma_u^2) / \sigma^2$

H_0: $\gamma = 0$ which is rejected at 5% level of significance against the alternative hypothesis, H_1: $\gamma > 0$.

If the null hypothesis is accepted, the inefficiency effects u_i are absent from the model. This means that fully technical efficiency is rejected at 5% level of significance. If the null hypothesis is true, the stochastic frontier model reduces to an Ordinary Least Square (OLS) model with normal errors. If the model is inefficient, the technical inefficiency can be calculated by equation (7). Then the technical efficiency can be determined as following function;

$$TE_i = \exp(-u_i)$$

As discussed in section 3.2.4, the production form of Stochastic Production Frontier Approach (SPFA) utilizes only one single output data to estimate technical efficiency using input variables. SPFA does not use any price data. Price data are not required for SPFA (Fried et al., 2008). Further, SPFA uses data with quantity only to develop the technical efficiency model as described in section 3.2.4. As SCFA & DEA are directly linked with price data, these two techniques are not considered to analyse technical efficiency for NWSDB. Hence, the SPFA is more relevant for studying the structure of technical efficiency than the direct estimation of economic efficiency for NWSDB.

3.3.1. The Model Proposed for NWSDB

In order to measure technical efficiency in water utilities, different specifications have been made for the problem to be solved depending on the variables used. Therefore, equation (3) in section 3.3 is converted to log (ln) form due to convenience for the SPF function as described in section 3.2.4 past literatures. This enables that all input and output data should be converted to log (ln) form before creating the data file because the Translog estimates are highly satisfactory (Greene, 2008 and Parmeter & Kumbhakar, 2014). Therefore, the proposed significant translog stochastic production functional model as an initial model for NWSDB described in equation (3) can be expressed as equation (11).

(11) $\ln y_i = \beta_0 + \sum_{i=1}^{n} \beta_i \ln(x_i) + v_i - u_i = \beta_0 + \sum_{i=1}^{n} \beta_i \ln(x_i) + \varepsilon_i$

Here i= 1 to 21 denotes the regions.

According to variables, the model can be articulated as in equation (12);

$$(12)\quad \ln(CWP) = \beta_0 + \beta_1 \ln(DC) + \beta_2 \ln(NDC) + \beta_3 \ln(DCONS) + \beta_4 \ln(NCONS) + \beta_5 \ln(QOW) + \beta_6 \ln(O\&M) + \beta_7 \ln(RM) + \beta_8 \ln(CCR) + V_{it} - U_{it}$$

The notations of above function represent as follows.

OUTPUT VARIABLE

Y = CWP - Clear water Production (Volume m^3/month)

INPUT VARIABLES

For Stochastic Production Frontier:

DC - Domestic Connections (Numbers/month)

NDC - Non Domestic Connections (Numbers/month)

DCONS - Domestic Consumption (Volume m^3/month)

NDCONS - Non Domestic Consumption (Volume m^3/month)

QOW - Quality of Water (Number of sample tested/month)

O&M - O&M Staff (Numbers/month)

RM - Rectification of Meters (Numbers/month)

CCR - Consumer Complaints Received (Numbers/month)

Inputs for Technical Inefficiency model:

NRW - Non-Revenue Water volume (Volume m3/month)

CDM - Connections due to Defective Meters (Numbers/month)

DCDM - Defective Connections other than Defective Meters (Numbers/month)

The mean technical inefficiency described in equation (9) can be demonstrated as the following equation (13) with its (Log) ln form.

$$(13)\quad \mu_i = \delta_o + \delta_1 \ln(NRW) + \delta_2 \ln(CDM) + \delta_3 \ln(DCDM)$$

Where, δ represents elasticity values for inefficiency.

Using above translog stochastic production functional model, NWSDB which covers 24 Island wide regions is evaluated and estimated for technical inefficacy using data for five years from 2010 to 2014. Each region is considered as an independent organization which produces piped born water.

The model is tested and estimated by using the Maximum Likelihood (ML) method in order to estimate the parameters of the stochastic production frontier and the variables of the inefficiency model simultaneously.

The inference of the SPFA is estimated using 'STATA' software package which follows the maximum likelihood (ML) estimates of the parameters for this model. After obtaining parameters of the model, a hypothesis test will be done. If the model is 'yes', technical efficiency is estimated as described in section 3.3.

The research design summary can be represented as in subsection 3.3.3.

3.3.2. Obtaining DATA for analysis

The data for proposed SPF model is dependent on 11 input variables and a single output variable. The data for this research lie on secondary data collected internally (monthly raw data directly from NWSDB data base) and externally (published in quarterly and annual reports of NWSDB) for the period of five years from January 2010 to December 2014. Out of 11 input variables, 8 independent variables which affect clear water production are proposed to SPF model. The balance 3 variables are proposed as controllable variables for equation (13), mean Technical Inefficiency as mentioned in section 3.3.1.

The proposed 12 variables including input and output variables have to be collected through monthly observational data from the 24 Regional Managers' Centres (Regions). Each of the 24 Regions prepares its Performance of Commercial Activity (PCA) report monthly, on actual observations. These monthly performance reports include variables based on KPI, like total water production of a particular month, domestic and Non-domestic water connection details, billing and collection data, metering data (Replacements, disconnections, legal actions etc.), NRW data, public complaints, defective meters, details of estimated bills, revenue/expenditure data etc. Then, RSCs send these data through the performance report to the relevant departments (especially Corporate Planning Division, Billing and Collection department of Commercial Division, Accounts Division and NRW section) of NWSDB head office. These departments enter all the relevant data to the data base.

The monthly Management Information (MI) report is a group effort involving Corporate Planning Division, Billing and Collection department of Commercial Division, Accounts Division and the NRW section, aiming to include all the information on KPI variables. This MI report is delivered to RSCs Island wide and the NWSDB Library. The NWSDB Library has the copy of each monthly MI report. Additionally to the PCA reports and MI reports, all 24 regions prepare Annual Implementation Programme (AIP) reports. The AIP report includes monthly observational data such as new water connection details, volume of water production, NRW %, details of rectification of defective meters, details of consumer complaints and operational cost data. This AIP is also available in the NWSDB Library. Further, NWSDB's Billing and Collection department of Commercial Division presents monthly performance reports which include all connections and consumptions data on regional monthly observations. These reports include observational data like details of domestic connections, non-domestic connections, domestic consumptions, non-domestic consumptions, quantity sold, revenue, billing & collection details and billing information.

Thus, monthly observational data of inputs and outputs can be collected from the above reports of NWSDB and from the data base for the period of January 2010 to December 2014.

3.3.3. Research design as a summary

Given below is the research design as a summary

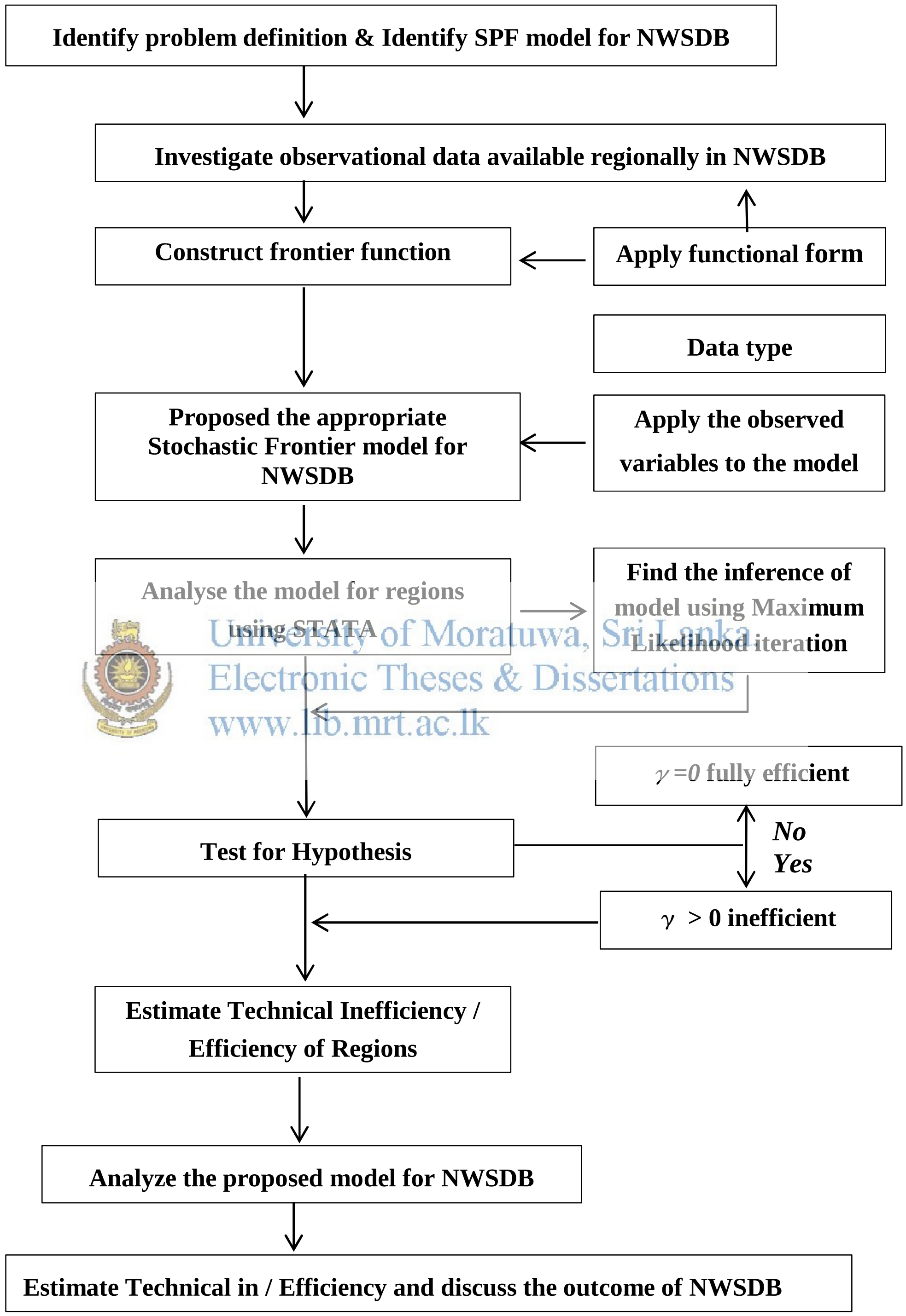


Figure 3.2: Research Design

3.4. Summary

The main focus of this chapter is to investigate relevant techniques available for evaluating efficiency and performance level of NWSDB. Therefore, the most famous frontier approaches for water utilities were identified as DEA and SFA.

DEA method is the first choice of many econometricians used by water utilities, but there is no place to account for noise in this method. Stochastic frontier analysis overcomes this problem of unaccountability of noise and includes an error variable u_i in the function. Accounting for noise is adopted only by SFA. However, DEA and SCFA approaches discuss about economic efficiency with price data. These approaches depend on cost functions. Due to the absence of good proxies to measure the variables in the cost function, especially capital prices, dummy variables have to be introduced. In the case of SPFA of parametric method, this approach does not use any price data and estimates with technical efficiency.

Therefore, this study uses SPFA. Based on methodology found for NWSDB, the proposed efficiency model is designed. Then, research designed diagram is finalized to carry out the analysis.

CHAPTER 4

DATA ANALYSIS AND FINDINGS

4.1. Introduction

This chapter presents the data description, data collection effort and data analysis with key research findings. Therefore, constructed stochastic model described in section 3.3.1 for NWSDB is analysed regionally with the observational data which are collected directly from NWSDB. Accordingly, the main purpose of this chapter is to estimate technical efficiency of NWSDB. The results are discussed here after obtaining results of the analysis. Here this study uses 60 observations for a single variable regional data to test the proposed SPF model. Therefore, this analysis uses 660 observations for 11 variables because the statistical software 'STATA' requires at least 50 observations for a single variable to analyse the model.

The section comprises of three subsections. Section 4.2 discusses data collection procedure with subsection 4.2.1, 4.2.2 and 4.2.3. Section 4.3 discusses the data analysis and key research findings using proposed model for NWSDB. The section ends with some concluding remarks in Section 4.4.

4.2. Data Collection

At present, Sri Lanka is covered geographically, through eleven (11) Regional Support Centres (RSCs) by NWSDB (Key Performance Indicator report, NWSDB, December 2014). With the expansion of water supply facilities, RSC's were divided into the 24 Regional Manager's Centres (Regions). All the regions produce drinking water through production schemes, do regular operation & maintenance work and distribute water to consumers as described in the above chapters. Finally, revenue is generated regionally to NWSDB. These regions are differing in terms of size (Area, Population, Urbanization and Industrialization) as well as in some environmental conditions. This section comprises three sub sections.

4.2.1. Data description

The proposed model described in section 3.3.1 uses monthly observations for the period of 2010, 2011, 2012, 2013 and 2014 to analyse technical efficiency for NWSDB. The variables for this analysis are based on the service indicator, operational and customer service indicators which are published annually in the Key Performance Indicator Reports (KPI) through the Corporate Planning Division of the NWSDB. In addition, important and significant data considered by NWSDB is also included in the analysis. Currently, the NWSDB measures its performance yearly by using simple ratio measures as mentioned below. The KPI report used Island-wide annual observational data (mean values) for the KPI.

(1) Service Indicator

- Piped Water Connected Coverage (%) = $\frac{\text{People served by piped water}}{\text{Total population of the area}} \times 100$

- Water Quality (%) = $\frac{\text{No of samples passing bacteriological tests}}{\text{No of samples tested}} \times 100$

(2) Operational Indicator

- Non- Revenue Water (%) = $\frac{\text{(Water produced – water consumption)}}{\text{Water produced}} \times 100$

- Staff per1,000 Connections = $\frac{\text{Total Staff} \times 1000}{\text{Total connections}}$

- Defective meters per 1,000 connections = $\frac{\text{No of defective meters} \times 1000}{\text{Total connections}}$

- Estimated bills per 1,000 connections = $\frac{\text{No of estimated bills} \times 1000}{\text{Total connections}}$

(3) Customer Service Indicator

- Customer Complaints/1,000 connections) = $\frac{\text{No of customer complaints} \times 1000}{\text{Total connections}}$

This study used monthly observed data. In this analysis, price data is excluded as described in section 3.3 and 3.3.1 because price data is important for economic efficiency. The variables for this analysis are based on the above three indicators. In this analysis, eleven (11) monthly observational data as input variables and Clear Water Production per month as output variable are included. The unit of measures are described as follows.

DC	-	Domestic Connections (Numbers/month)
NDC	-	Non Domestic Connections (Numbers/month)
DCONS	-	Domestic Consumption (Volume m^3/month)
NDCONS	-	Non Domestic Consumption (Volume m^3/month)
QOW	-	Quality of Water (Number of sample tested/month)
O&M	-	O&M Staff (Numbers/month)
RM	-	Rectification of Meters (Numbers/month)
CCR	-	Consumer Complaints Received (Numbers/month)
NRW	-	Non-Revenue Water volume (Volume m3/month)
CDM	-	Connections due to Defective Meters (Numbers/month)
DCDM	-	Defective Connections other than Defective Meters (Numbers/month)
CWP	-	Clear Water Production (Volume m^3/month)

Out of eleven variables, DC, NDC, DCONS and NCONS variables are included additionally to KPI variables. In place of KPI indicator called defective metres, variable RM is included. A customer complaint which is taken as KPI indicator of performance report is considered as CCR for this analysis. Instead of NRW %, volume of non-revenue water of the total production volume is considered to observational data. Further, instead of the variable estimated bills, the connections related to estimated bills are divided into two observations such as connections due to Defective Meters (CDM) and Defective Connections other than Defective Meters (DCDM).

4.2.2. Sampling technique

As mentioned above in section 4.2, the whole island is sub-divided into 24 Regional Manager's Centres (Regions). Here, the analysis considers 21 regions. Colombo City region is excluded because NRW volume is almost 50% of the total production of water. This implies the inefficiency. In addition, the Colombo City region is very complicated and therefore difficult to monitor for observations. The RSC North is comprised of 3 regions which are Jaffna, Mannar and Vavuniya. Due to the war situation which prevailed in these regions up to 2009, the regions Mannar and Vavuniya were separately considered for data collection only after 2010. Yet, the circumstances in these two regions made it difficult for the NWSDB to collect and maintain the relevant data and keep them up to date in the database. Therefore, in this study, Mannar and Vavuniya regions are excluded. The balance 21 regions are considered in this study to estimate the overall technical efficiency of NWSDB using the model described in section 3.3.1 because all regions are evaluated independently, using the model. These 21 regions are shown in Table 4.1. The classifications of these regions are in accordance with the Billing and Collection department of the Commercial Division. These regions virtually cover the whole island. Therefore, no sampling techniques are applied here, as almost the whole population is considered for the analysis.

Table 4.1: Regional Manager's Water Production Centres

RSC		Regions		Total
Western Central	TEC-North	TEC-South	Colombo City (Excluded)	02
Western South	TSC-Dehiwala	Kalutara	Panadura / Horana	03
Western North	TNC	Gampha		02
Southern	Matara	Hambantota	Galle	03
Central	Kandy (North, East, South)			01
Sabaragamuwa	Ratnapura	Kegalle		02
Uva	Bandarawella	Monaragala		02

RSC		Regions		Total
North	Jaffna	Mannar (Excluded)	Vavuniya (Excluded)	01
Eastern	Trincomalee	Ampara	Akkaraipattu	03
North Central	Anuradapura			01
Wayamba	Kurunegala			01
Total				**21**

Note: RSC = Regional Support Centre TEC = Town East Colombo
TSC = Town South Colombo TNC = Town North of Colombo
(Source: Billing and Collection department of Commercial Division, NWSDB)

4.2.3. Data collection technique

The secondary data for this analysis is directly collected through NWSDB. This analysis requires at least sixty (60) monthly observations for single variables. Therefore, the monthly observational data called as Clear Water Production (CWP), Domestic Connections (DC), Non-Domestic Connections (NDC), Domestic Consumptions (DCONS) and Non-Domestic Consumptions (NDCONS) were collected directly through the Billing and Collection department of Commercial Division of NWSDB (Annex 02 – Excel sheet for Data and Annex 03 – Approval for data collection). Billing and Collection department prepares the monthly performances report based on the regional Manager's monthly performance reports.

In addition, the monthly observational data for QOW (Quality of Water) and O&M Staff were collected from the data base of the Corporate Planning Division of NWSDB (Annex 02). Further, the monthly observational data for Rectification of Meters (RM) and Consumer Complaints Received (CCR) were collected through AIP report of NWSDB. These reports are available in the Library of NWSDB. The observational data Non-Revenue Water volume (NRW) was collected based on the MI report published through NWSDB library and data base of Corporate Planning Division of NWSDB. The variable data for Connections due to Defective Meters (CDM) and Defective Connections other than Defective Meters (DCDM) were collected through data base of Corporate Planning Division of NWSDB (Annex 02).

The Annual Reports of NWSDB for 2007, 2008, 2009 and 2010 and Corporate Plans for NWSDB, 2007- 2011; 2007 and 2012-2016; 2012 were followed as a guideline for observational data collection, appropriate to the model described in section 3.3.1. The KPI reports for 2010, 2011, 2012, 2013 and 2014 were also considered when data was collected. All this information is freely available in NWSDB web site (www.nwsdb.lk).

Past data which is not available in the library and NWSDB web site for periods starting from 2010 to 2014 was collected directly from Billing and Collection Department of Commercial Division and Corporate Planning Division of NWSDB as hard copies from data base. Most of the relevant data for this analysis has been collected through the Billing and Collection department of Commercial Division and Corporate Planning Division of NWSDB, through letters of requests addressed to the head of these two Divisions, explaining the motive behind such collection (Annex 03).

4.3. Data Analysis and Findings

The purpose of this chapter is to explain the findings through the empirical study in a detailed manner. Therefore, the main objective of this section is to analyse data to find inference of the proposed model because analysis gives the information regarding technical inefficiency term u_i. To estimate technical efficiency, the SPF model which described as equation (12) in section 3.3.1 is presented as follows and called as model (01);

Model (01)

$$\ln(CWP) = \beta_0 + \beta_1 \ln(DC) + \beta_2 \ln(NDC) + \beta_3 \ln(DCONS) + \beta_4 \ln(NDCONS) + \beta_5 \ln(QOW) + \beta_6 \ln(O\&M) + \beta_7 \ln(RM) + \beta_8 \ln(CCR) + V_i - U_i$$

4.3.1. The analysis of model and findings for selected regions

First, the proposed model was tested for a selected region. For an example, the region Ratnapura was analysed for the period of 5 years from 2010 to 2014 using above SPF model. The observed data was transformed to natural logarithm of the data before fitting a log (ln) Stochastic Production Frontier. The elasticity values (β_i) and inference of the data was estimated using 'STATA' software package which follows the maximum likelihood (ML) iteration for the parameters. The 'STATA' requires at least 50 observations for a single variable to analyse the model. Here, this study used 60 observations for a single variable which are available in annex 02. Therefore, this analysis uses 660 observations for eleven input variables. The summary of 'STATA' output for Ratnapura region is given below and tabulated in Table 4.2. The results of STATA output are included in annex 01.

Table 4.2: The Summary of 'STATA' output for Ratnapura

Frontier: Y(CWP) = X1(DC), X2(NDC), X3(DCONS), X4(NDCONS), X5(QOW), X6(OM), X8(RM), X9(CCR)

Stoc. Frontier normal / half-normal model   Number of Observations = 60

Log likelihood = 103.46088

YCWP |	**Coef.**	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**	
X1DC |	0.286203	0.0000167	1.7e+04	0.000	0.2861703	0.2862358
X2NDC |	0.1459129	0.0000122	1.2e+04	0.000	0.145889	0.1459367
X3DCONS |	0.0637203	8.27e-07	7.7e+04	0.000	0.0637187	0.0637219
X4NDCONS |	0.1854007	2.52e-06	7.4e+04	0.000	0.1853957	0.1854056
X5QOW |	0.0605708	4.93e-06	1.2e+04	0.000	0.0605612	0.0605805
X6OM |	-0.0131893	6.78e-07	-1.9e+04	0.000	-0.0131906	-0.013188
X8RM |	-0.0353976	2.51e-06	-1.4e+04	0.000	-0.0354025	-0.0353927
X9CCR |	0.0182004	2.26e-06	8064.77	0.000	0.018196	0.0182048
_cons |	6.256544	0.0001072	5.8e+04	0.000	6.256334	6.256754
/lnsig2v |	-38.64462	197.0124	-0.20	0.844	-424.7818	347.4926
/lnsig2u |	-4.900279	0.1825742	-26.84	0.000	-5.258118	-4.54244
sigma_v |	4.06e-09	4.00e-07		5.75e-93	2.86e+75	
sigma_u |	0.0862816	0.0078764		0.0721463	0.1031862	
sigma2 |	0.0074445	0.0013592		0.0047806	0.0101084	
lambda |	2.13e+07	0.0078764		2.13e+07	2.13e+07	

As observed in the summary of STATA output of Table 4.2, the output from frontier includes estimates of the standard deviations of the two error components σ_v and σ_u which are labelled as sigma v and sigma u, respectively. In the log likelihood, they are parameterized as $lnsig^2$ v and $lnsig^2$ u and these estimates are labelled as /lnsig2v and /lnsig2u in the output. Frontier also reported two other useful parameterizations. The elasticity values for input variables were summarized as coef. The estimate of the total error variance, $\sigma^2 = \sigma_u^2 + \sigma_v^2$, was labelled sigma2, and the estimation of the ratio of the standard deviation of the inefficiency component to the standard deviation of the noise component, $\lambda = \sigma_u / \sigma_v$, was labelled as lambda.

<u>Findings</u>

According to STATA summary Table 4.2, the findings from the analysis of the SPF model for Ratnapura were summarized as follows. Therefore, the estimated elasticity values and inference of the proposed SPF model for Ratnapura can be presented in Table 4.3 and Table 4.4 respectively.

Table 4.3: Elasticity Estimates for Ratnapura

	Parameters	Estimated Elasticity
β_0	constant	6.256
β_1	ln(DC)	0.286
β_2	ln(NDC)	0.145
β_3	ln(DCONS)	0.063
β_4	ln(NDCONS)	0.185
β_5	ln(QOW)	0.060
β_6	ln(O&M)	-0.013
β_8	ln(RM)	-0.035
β_9	ln(CCR)	0.018

Table 4.4: The inference of the model

Parameters	Estimated values
σ^2	0.0074445
σ_u	0.0862816
σ_v	4.06e-09
$\lambda = \sigma_u / \sigma_v$	2.13e+07

According to results of the analysis for Ratnapura region described in Table 4.3 and 4.4, it is found that proposed production frontier model for Ratnapura is having σ_u inefficiency component of u_i. Therefore the hypothesis test can be carried out. The test statistic is described in section 3.3 and presented in equation (10);

$$\gamma = (\sigma_u^2) / \sigma^2$$
$$= \frac{(0.0862816)^2}{0.0074445} = 0.99$$

Here, $\gamma > 0$. The relative magnitude of variance is $\gamma > 0$.
Hence, H_0: $\gamma = 0$ is rejected against the alternative hypothesis
According to the test statistic, it is found that proposed model is inefficiency model.

According to γ estimation, it is found that the proposed model is technical inefficiency model and NWSDB can be analysed using the proposed model. The Maximum Likelihood iteration method estimated parameter gamma as (0.99). Past literature pointed out that gamma is the main source of the deviation of inefficiency (Berg, 2010). Another finding of this analysis is that mean Technical Inefficiency and mean Technical Efficiency (TE) can be estimated because σ_u was estimated.

As σ_u was estimated by the model, the mean technical inefficiency for Ratnapura is estimated by using the equation (7) described in section 3.3 as follows.

$$E(\varepsilon) = E(u) = \{ - \frac{\sqrt{2}}{\sqrt{\pi}} \sigma_u \}$$
$$= (0.068162464) = 6.816 \%$$

Hence, mean Technical Efficiency of the selected Ratnapura region is evaluated as follows;

Technical Efficiency (TE) = $\exp^{(-ui)}$ = 93.184 %

Therefore, it is found that, the technical inefficiency score for Ratnapura region is estimated as 6.816 %. According to estimation of TE, it is found that TE score for

Ratnapura region is 93.184 %. Another important finding is the estimated elasticity values using the proposed model. Based on the estimated elasticity values presented in Table 4.3, it is found that the elasticity value of Domestic Connection (DC) is most significant independent variable and value (0.286) is positive. In addition, it is found that second most significant variable is Non-Domestic Consumption (NDCONS) and value (0.185) is positive. The elasticity values describe the effects of the variables to the production function. Therefore the proposed model can be adopted to analyse the NWSDB.

Further, same test statistics described above were continued for all the 20 regions to test the model. The test statistic found that $\gamma > 0$ for all selected 20 regions. Further it was found that the proposed SPF model was a technically inefficiency model through which technical efficiency can be estimated. The mean technical inefficiency and mean technical efficiency for the 20 regions which were thus estimated are presented in Table 4.5 and the graphical representation is shown in Figure 4.1.

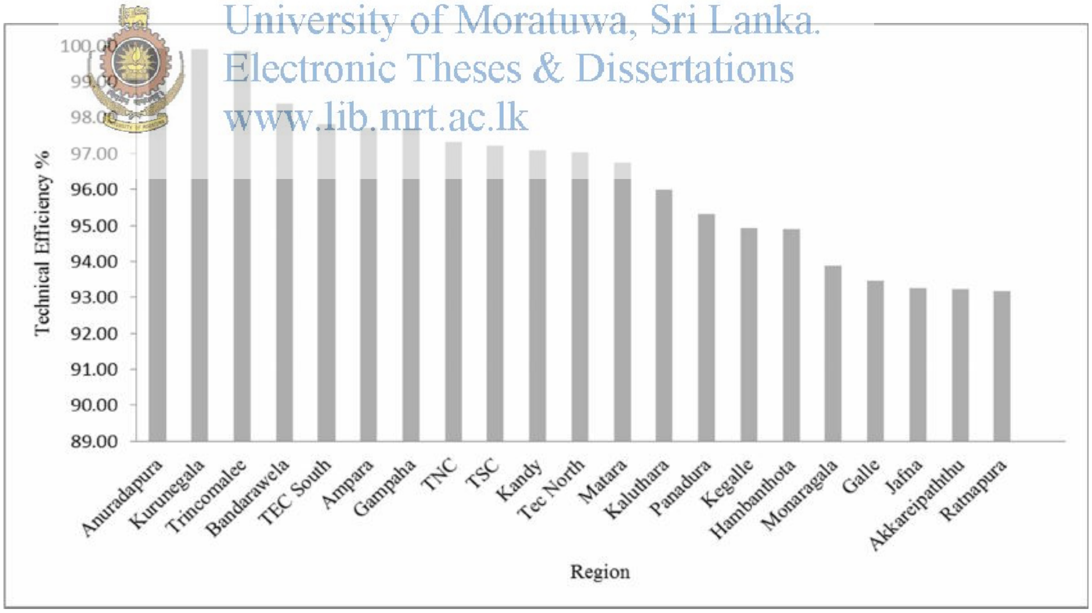


Figure 4.1: Mean Technical Efficiency vs. Regions

Table 4.5: Technical Inefficiency and Technical Efficiency scores regionally

Regions	Mean Technical Inefficiency	Mean Technical Efficiency
ANURADAPURA	0.081	99.918
KURUNEGALA	0.090	99.909
TRINCOMALEE	0.156	99.843
BANDARAWELLA	1.603	98.396
TEC SOUTH	2.173	97.826
AMPARA	2.288	97.711
GAMPAHA	2.315	97.684
TNC	2.676	97.323
TSC	2.793	97.206
KANDY	2.906	97.093
TEC NORTH	2.965	97.034
MATHARA	3.251	96.748
KALUTARA	4.002	95.997
PANADURA	4.680	95.319
KEGALLE	5.089	94.910
HAMBANTHOTA	5.100	94.899
MONARAGALA	6.124	93.875
GALLE	6.531	93.468
JAFFNA	6.754	93.245
AKKRAIPATTU	6.754	93.240
RATNAPURA	6.816	93.183

According to the graphical representation of regional efficiency scores in Figure 4.1, it is found that most efficient regions having technical efficiency over 99% are Anuradapura, Kurunegala and Trincomalee respectively while less efficient regions are Ratnapura, Akkaraipattu and Jaffna. Therefore, above analysis confirmed that the selected SPF model is proficient to define the technical efficiency of NWSDB, because this model was tested on 21 regions and satisfied the test. In this context, NWSDB is analysed using the above SPF model.

4.3.2. Estimation of overall technical efficiency for NWSDB and findings

The SPF model already tested on 21 regions was proposed to evaluate technical efficiency (overall) of NWSDB as follows. The β values and inference of the proposed model for NWSDB were estimated using observational data covering the 21 regions, for a five year period from 2010 to 2014 by applying 'STATA' software analysis. The monthly regional observational data were considered to estimate elasticity values and technical efficiency yearly. For a single variable, 252 observations (21 regions x 12 observations per year) were included to estimate efficiency yearly. The literature pointed out that the accuracy of the 'STATA' analysis increased when the variable included more than 100 observations.

The Analysis and Estimation TE for NWSDB

The SPF model which was tested on 21 regions is now proposed to evaluate NWSDB;

$$\ln(CWP) = \beta_0 + \beta_1 \ln(DC) + \beta_2 \ln(NDC) + \beta_3 \ln(DCONS) + \beta_4 \ln(NDCONS) + \beta_5 \ln(QOW) + \beta_6 \ln(O\&M) + \beta_7 \ln(RM) + \beta_8 \ln(CCR) + V_{it} - U_{it}$$

This tested model (called as Model 01) was analysed using 'STATA' software using Maximum Likelihood iteration method and estimated mean technical inefficiency and mean technical efficiency yearly for the five year period of 2010, 2011, 2012, 2013 and 2014 using 21 regional monthly observations. The yearly output of 'STSTA' was attached to annex (01).

Findings for NWSDB

According to STATA output, the ratio of variance of σ_u^2 and variance of the model σ^2 were estimated and tabulated in Table 4.6.

Table 4.6: Estimated values for γ

Year	γ
2010	0.65
2011	0.74
2012	0.72
2013	0.82
2014	0.86

Table 4.6 shows $\gamma > 0$ is for the period of five years. Greene (2008) and Fried et al. (2008) demonstrated, the useful indicator of the influence of the inefficiency component in the overall variance γ must be between 0 and 1. Therefore, it is found that the proposed production frontier model for NWSDB has the inefficiency component u_i. The entire deviation of the model is due to inefficiency term u_i which is represented in the model. As mentioned in section 4.3.1, the mean technical inefficiency can be estimated. Based on the 'STATA' output, the estimated standard deviation, mean technical inefficiency and mean efficiency scores for NWSDB over the five year period are presented in Table 4.7. The graphical presentation for efficiency trend for the five years is illustrated in figure 4.2.

Table 4.7: Overall Technical Inefficiency and Technical Efficiency of NWSDB

Year	σ_u (Standard Deviations)	Inefficiency %	Technical Efficiency %
2010	0.0965922	7.63	92.37
2011	0.1051314	8.30	91.70
2012	0.1318029	10.41	89.59
2013	0.1075431	8.50	91.50
2014	0.1083167	8.56	91.44

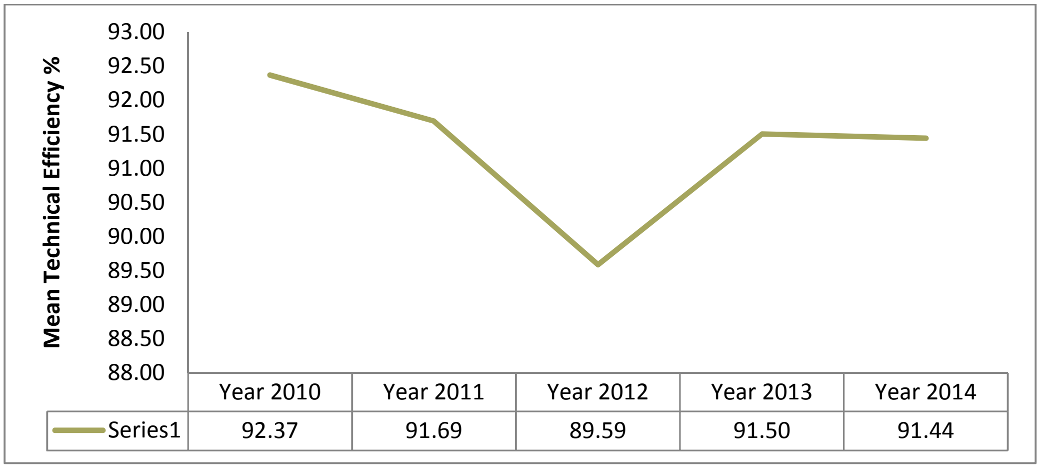


Figure 4.2: Mean Technical Efficiency Trend (NWSDB) for five years

According to above Table 4.7, it is found that the average Technical Efficiency for NWSDB for the period of five years from 2010 to 2014 is 91.3%. In addition, it is found that the SPF model estimated the largest mean technical inefficiency as 10.41% in 2012. According to the estimation of SPF model for NWSDB, it is found that maximum mean technical efficiency (92.37%) was in 2010. Further, this analysis revealed that less TE was recorded during 2013 and 2014 periods when compared to 2010.

Based on figure 4.2, the most valuable finding is that mean technical efficiency trend for the period of five years for NWSDB is decreasing at decreasing rate (slightly). Its gradient is decreasing. Further, it is found that high gradient of TE, when compared to 2012, was achieved during 2013 (almost 2% increment of TE) while less efficiency showed in 2014.

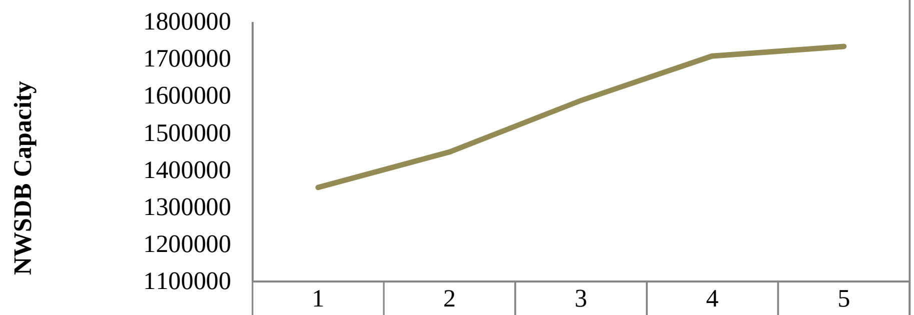
Performance assessment and efficiency evaluation of public utilities like NWSDB, with the use of benchmarking methodologies (such as Stochastic Frontier Approach), have not been a regular practice in Sri Lanka up to now. According to SPF analysis of this study, it is found that the average Technical Efficiency for the period of five years from 2010 to 2014 is 91.3%. However, NWSDB's technical efficiency results lie in contrast to those achieved in other parts of the world. For example

Bhattacharyya et al., (1995) revealed the average technical efficiency of the Municipal Government's water utilities in California is 90% ; Faria, Souza & Moreira (2005) proposed production frontier and concluded the average technical efficiency estimated for the public sector water utilities is 72% in Brazil; Vishwakarma, & Kulshrestha (2010) finalised mean technical efficiency of production frontier is 84.47% for the water utilities of urban cities in the state of Madhya Pradesh, India; Further, Corton & Berg (2009) analysed cost frontier and found technical efficiency is almost 100% in Central America; Zschillea & Walter (2012) found, the maximum technical efficiency score is 95.12% based on data from 373 public and private water utilities in Germany. Comparing with the above technical efficiency scores, the technical efficiency achieved by NWSDB can be accepted as a good achievement marginally. It is quite reasonable to accept as a success. This amply proves that the results of this analysis supports the results achieved by the above mentioned water utilities in other parts of the world.

According to the analysis, the performance of NWSDB can be presented alternatively as follows. Based on above efficiency scores in Table 4.7, NWSDB capacity (Total water connections) and its efficiency can be presented in Table 4.8. Further, the graphical presentation for capacity with the Technical efficiency changes for the five years can be illustrated in figure 4.3.

Table 4.8: Technical Efficiency and NWSDB Capacity (Total water connections)

Year	**Efficiency Score %**	**NWSDB Capacity (Total water connections per year)**
2010	92.37	1,353,573
2011	91.70	1,449,301
2012	89.59	1,587,663
2013	91.50	1,707,742
2014	91.44	1,733,771



	1	2	3	4	5
Year	2010	2011	2012	2013	2014
Efficiency Score	92.37	91.70	89.59	91.50	91.44
NWSDB Capacity (Total water connections per year)	1,353,573	1,449,301	1,587,663	1,707,742	1,733,771

Figure 4.3: Capacity vs. Efficiency

According to above Table 4.8, it is found that NWSDB capacity is increasing at a decreasing rate over the five year period from 2010 to 2014 when technical efficiency is decreasing over the same period of time.

The very important feature of the Model 01 is that the estimated elasticity values describe the effect to the SPF model. Therefore, the proposed model (01) as described in section 4.3.1 can be presented with the estimated elasticity values. Here, the elasticity values based on 'STATA' outputs for the year 2014 are presented to describe the effect of variables to the production function. It is found that the model can be articulated with elasticity values as follows;

$$\begin{aligned} \ln (CWP)_{2014} = {} & 0.851 + (0.010) \ln (DC) + (0.017) \ln (NDC) + \\ & (0.7737405) \ln DCONS) + (0.2340334) \ln (NDCONS) + \\ & (-0.0368733) \ln (QOW) + (-0.0232761) \ln (O\&M) + \\ & (-0.0058525) \ln (RM) + (0.0053761) \ln (CCR) + V_{it} - U_{it} \end{aligned}$$

In this context, the proposed model (01) is better to describe stochastic production function of NWSDB. Therefore, the following findings were observed with the proposed model for the year 2014 as mentioned above.

(a) It is found that the most significant variable for NWSDB SPF model (01) is Domestic Consumptions (DCONS) during 2014. Elasticity of the domestic consumption is positive and significant and plays a very important role in the production of clear water. The elasticity value of DCONS is 0.7737405. If domestic consumption will increase by ten per cent (10%) then clear water production of the NWSDB will increase by 7.70% as per the proposed model with elasticity values.

(b) The second most significant variable for NWSDB SPF model (01) is Non-Domestic Consumption (NDCONS). It is found that, elasticity of the NDCONS (0.2340334) is positive and significant. If non-domestic consumption increases ten per cent (10%) then clear water production of the NWSDB will increase by 2.34%.

(c) In addition to above significant two variables, it is found that, the elasticity values of Domestic Connections (DC), Non-Domestic Connections (NDC) and Consumer Complaints Received (CCR) are positive and significant variables to clear water production.

(d) Further, It is found that Quality of Water (QOW) (Number of samples tested/month) and Rectification of Meters (RM) (Numbers/month) are negatively significant variables for the proposed model (02). If number of samples tested/month decreases, clear water service efficiency will decrease. Because of this reason, clear water production has to be adjusted until water quality is reached. If elasticity value (-0.0368733) of QOW increases ten per cent then clear water production of the NWSDB has to be adjusted by 0.36% until the standard of water quality is reached. Rectification of Meters (RM) (Numbers/month) (-0.0058525) suggest that clear water production has to be adjusted until defective meters are rectified.

(e) It is found that the elasticity values for O&M are (- 0.0232761). This shows that O&M is a negatively significant variable.

In addition to the above findings, the most important finding was that the mean technical inefficiency model, described in section 3.3 (equation (13), can be described with elasticity values for the year 2014 as follows. The inefficiency can be described by using firm's controllable variables as mentioned in earlier sections. Then, technical inefficiency of the NWSDB can be described with the estimated elasticity values. The elasticity values were estimated by using STATA with the maximum likelihood iteration method using controllable variables. The output is presented in Table 4.9.

Table 4.9: The Estimated Elasticity values for Mean Technical Inefficiency Model

Frontier YCWP X1DC X2NDC X3DCONS X4NDCONS X5QOW X6OM X8RM X9CCR, uhet (X7NRW X10CDM X11DCDM)

YCWP |	**Coef.**	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**	
X7NRW |	-1.644549	0.2170709	-7.58	0.000	-2.07	-1.219098
X10CDM |	-0.0519853	0.08293	-0.63	0.531	-0.2145251	0.1105546
X11DCDM |	0.1434238	0.0976509	1.47	0.142	-0.0479684	0.334816

Therefore, it is found that the mean technical inefficiency for the year 2014 (μ_{2014}) can be shown as follows.

$$\mu_{2014} = 14.02 + (-1.64) \ln (NRW) + (-0.05) \ln (CDM) + (0.14) \ln (DCDM)$$

The proposed mean Technical Inefficiency model (02) for NWSDB presents more valuable information to NWSDB. This study proposes that the mean technical inefficiency is entirely caused by the volume Non- Revenue Water (NRW), Connections due to Defective Meters (CDM) and Defective Connections other than Defective Meters (DCDM). The estimated inefficiency elasticity values revealed the following findings;

(a) It is found that volume of Non- Revenue Water loss has a negative sign; ML estimate of this parameter is equal to (-1.64). This shows that a ten per cent increment in unaccounted water loss will increase inefficiency of the utility by 16.4%. It is very clear that NWSDB considers that the NRW variable is the most significant variable for NWSDB, and that it should be controlled in many ways. Every NWSDB annual report mentioned that many steps were taken to reduce Non- Revenue Water loss due to the loss of water volume of total water production. Because of the Non- Revenue Water loss, consumers have to incur additional cost for each water unit that they consumed (Annual Report, NWSDB, 2010). The KPI report also identified Non- Revenue Water variable as a key significant variable to be controlled by NWSDB.

(b) It is found that the other most important variable for mean inefficiency model is Connections due to Defective Meters. This variable is negative (ML estimate is equal to (-0.05)) and indicates that, ten per cent (10%) of increment in Connections are due to Defective Meters, and inefficiency of a utility will increase by 0.5%. Because of defective meters, bills are prepared, based on the estimated volume of consumed water as the actual consumption is not displayed on the meter. This shows that inefficacy occurs at NWSDB. KPI report also mentioned that the variable of estimated bills is a significant variable.

4.4. Summary

This chapter employed stochastic production function to estimate technical efficiency of NWSDB using monthly observed data over the five-year period from 2010 to 2014. The techniques were described in section 3.3 for NWSDB. Then NWSDB was evaluated using SPF model and estimated the inference of the model using STATA software package. The overall technical efficiency (mean value) is determined as a point estimate value for NWSDB. The above analysis confirmed that the proposed model for NWSDB was proficient to describe performance in the subject area of technical efficiency and its technical inefficiency.

The relevant findings and observations after analysing the model were presented in section 4.3. Therefore, the conclusions and recommendations on all the findings will be discussed in the following Chapter 5.

CAPTER 5

CONCLUSIONS AND RECOMONDATIONS

5.1. Introduction

The Corporate Planning Division of NWSDB presents its performances through its KPI report annually. On identifying significant flaws in this method of performance analysis, this research attempted to introduce an alternative method to evaluate and measure the performance of NWSDB, which would be more relevant and important as it could be used as a management tool. Thus, this study is a simple overview of the best practice for implementing an effective performance-based management tool.

In this context, the present study applied the parametric approach as a benchmarking method for NWSDB to present its performance instead of KPI. To achieve the above, the production efficiency of water utility is modelled using a trans-log Stochastic Production Frontier function for the NWSDB in Sri Lanka. The trans-log Stochastic Production Frontier allows the estimation of technical inefficiency and efficiency. Therefore, the present study has tested the constructed SPF model for 21 selected regions using monthly observational data from January 2010 to December 2014 and thereby proposed SPF model for NWSDB to estimate technical efficiency (overall) yearly. Finally, based on the findings obtained in the analysis, it discussed the performance of NWSDB.

This chapter completes the documentation of this study by presenting conclusions and recommendations. Therefore, the research objectives are reviewed and conclusions are presented. Recommendations for future research are also identified. Moreover, this chapter presents the summary of key research findings and conclusions in section 5.2, in section 5.3, recommendations are described and finally section 5.4 offers suggestions for further research.

5.2. Key Research Findings and Conclusions

The aim of the research was to analyse the efficiency level of NWSDB using an efficiency estimation model. Corresponding to this aim, four objectives have been formulated.

The first objective was to review existing literature, on performance measurement, within the spectrum of efficiency concepts in water utilities. It is found that 40% of literature is based on urban water utilities in the Western Europe, 30% is on the United States and the rest is on Japan, India, Malaysia, Australia, Asia and Africa. Further, literature review discussed the technique used in water utility sector in the past, country of study, the variables used, the possible outcome and the source. The 28 studies reviewed, identified the inputs and output relationships to support the techniques available for describing efficiency in water utilities in the world. In these 28 studies, performance measurement techniques and the type of input/output variables utilized for those analyses were identified. Finally, outcome of studies were identified. Therefore, the first objective is successfully achieved through the comprehensive literature review on performance and efficiency measures which have been used internationally in water utilities.

Objective two was to review methodology on efficiency measurement techniques and screen the best fit industry practice. As per the review, on efficiency measurement techniques available, it was found that primarily, the best approach for methodology was recognized as frontier approach under parametric approach to describe technical efficiency. Further, frontier approaches used in a few past studies in different production environments were also critically reviewed, to decide the best fit methodology for NWSDB. Finally, it was found that the best fit approach for NWSDB was SPFA and the base model proposed. Thus, objective 02 was successfully achieved.

The third objective was to develop the efficiency estimation model for NWSDB and test the model for regional managers' centres which produce pipe borne water. Based on SPF model, it was found that SPF model needs to be converted to log (ln) form due to convenience for the SPF function as described in section 3.3, because the translog estimates are highly satisfactory. Based on hypothesis test statistics ($\gamma > 0$), the test concluded that SPF model which was tested on 21 regions with observational data for the period of five years from 2010 to 2014, was an inefficiency model. Further it was concluded that the inferences of the model can be estimated using “STATA” software package using maximum likelihood iteration method. Finally, the analysis concluded that the developed SPF model is an inefficiency model and is suitable to describe technical efficiency. Further, SPF model was confirmed as a proficient model to describe the technical efficiency of NWSDB.

The fourth objective was to analyse and estimate efficiency level (point estimated value) for NWSDB using the developed estimation model. To achieve this objective, the NWSDB was analysed using SPF model which was tested on 21 regions and yearly technical efficiency estimated, starting from 2010, 2011, 2012, and 2013 and to 2014. Then efficiency trend for NWSDB was developed using estimated efficiency levels. Therefore, this section answers the objectives mentioned in chapter 1, section 1.3.

This study presented one effective approach to develop a performance measuring technique, using industry best practice. In this context, this study applied parametric approach and proposed Stochastic Production Frontier Model (Translog Model) to estimate Technical Efficiency as a performance measure. Further, this analysis revealed that best technical efficiency achievement was recorded in 2013 and value was 91.5% when compared to 2012. Based on elasticity values which were estimated using STATA, the most significant variable for SPF efficiency model (01) was domestic consumptions (DCONS) and non-domestic consumptions (NDCONS). In addition, the variables DC, NDC, CCR were identified as significant variables to describe the effect of SPF model.

Further, the mean technical inefficiency was described using controllable variables of this analysis and identified that NRW and CDM variables were the most significant variables that control mean technical inefficiency.

Finally, this study concluded that NWSDB can be analysed with the proposed SPF model as an alternative way to present the performance of NWSDB. Further, this analysis is of practical importance to the regulators, policy makers and the NWSDB managers who are responsible for the performances related to water management and water supply. In addition, the performance measures in the subject area of Technical Efficiency will help future developments in the Performance Reports such as MI, AIP and KPI as a means of further improving stakeholders' understanding of NWSDB. In conclusion, this research will provide guidance for presenting performance measures as an alternative for NWSDB, linking all the variables to a single model and presenting significant variables, with estimated elasticity values to describe the SPF model.

5.3. Recommendations

NWSDB is the principle water utility provider which produces and supplies piped born drinking water in Sri Lanka. Literatures revealed that measuring efficiency of a utility is an important part of economic decision-making. Therefore, this study focused on production approach to analyse the performances of NWSDB during the five year period from 2010 to 2014.

In this context, this study recommended the proposed translog Stochastic Production Frontier (SPF) model to analyse and estimate technical efficiency of NWSDB;

$$\ln(CWP) = \beta 0 + \beta_1 \ln(DC) + \beta_2 \ln(NDC) + \beta_3 \ln(DCONS) + \beta_4 \ln(NDCONS) + \beta_5 \ln(QOW) + \beta_6 \ln(O\&M) + \beta_7 \ln(RM) + \beta_8 \ln(CCR) + Vi - Ui$$

And its mean technical inefficiency (μ) model;

$$\mu_i = \delta o + \delta_1 \ln(NRW) + \delta_2 \ln(CDM) + \delta_3 \ln(DCDM)$$

The above two models can be proposed as best industry practices for performance measures in the management of water utilities in the subject area of efficiency. Finally, SPF model proposed for NWSDB will help future developments in the Performance Reports to have a better understanding of NWSDB performances.

This study is limited to piped borne water production through NWSDB schemes which produce clear drinking water as a production. The other means of water supply such as small rural water supply schemes using natural springs, protected dug wells, tube wells, rainwater harvesting systems and improved water sources are not considered for this analysis.

The above suggestions will directly benefit the NWSDB as a management tool to present performance achievements. Subsequently, this study can be expanded by identifying more variables to estimate technical efficiency with some possible alternations.

5.4. Further Research

Following could be given as suggestions for further research.

(A) This study can be further progressed to analyse all the Regional Managers' Centres by using propped SPF model, and thereby the significance and weight of elasticity, for variables which control the technical inefficiency can be identified. Then managers and regulators can identify the possible solutions to control the variables effectively.

(B) This study focused on quantities only for variables and discussed about Technical Efficiency only. No price data was included as variables. Therefore, this study can be extended using variables dependant on price data, which are mentioned in financial variables in KPI report. Further research can be carried out, with stochastic cost model with simple modification to the proposed model and the Economic Efficiency can be estimated then.

(C) This study can be exploited for further investigation on productive behaviour with portable water and wastewater services taken together, in the same study because NWSDB operates portable water schemes and sewerage water schemes regionally.

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Annex 01. Output of STATA analysis

- The output of 'STATA' for Ratnapura region

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  ___  ____  ____  ____  ____ (R)
 /__    /   ____/   /   ____/
___/   /   /___/   /   /___/   12.0   Copyright 1985-2011 StataCorp LP
  Statistics/Data Analysis            StataCorp
                                      4905 Lakeway Drive
     Special Edition                  College Station, Texas 77845 USA
                                      800-STATA-PC        http://www.stata.com
                                      979-696-4600        stata@stata.com
                                      979-696-4601 (fax)

Single-user Stata network perpetual license:
       Serial number:  93611859953
         Licensed to:  uditha
                       nws&db

Notes:
      1.  (/v# option or -set maxvar-) 5000 maximum variables

. import excel "C:\Users\UDITHA\Desktop\RATNAPURA.xlsx", sheet("Sheet1") firstrow

. frontier YCWP X1DC X2NDC X3DCONS X4NDCONS X5QOW X6OM X8RM X9CCR

Iteration 0:   log likelihood =  86.925723  (not concave)
Iteration 1:   log likelihood =  98.020479  (not concave)
Iteration 2:   log likelihood =  99.759975  (not concave)
Iteration 3:   log likelihood =   100.0437  (not concave)
Iteration 4:   log likelihood =   100.1389  (not concave)
Iteration 5:   log likelihood =  100.39367  (not concave)
Iteration 6:   log likelihood =   100.9253
Iteration 7:   log likelihood =  102.04505
Iteration 8:   log likelihood =  102.64175
Iteration 9:   log likelihood =  102.94513
Iteration 10:  log likelihood =   103.1941
Iteration 11:  log likelihood =  103.30957
Iteration 12:  log likelihood =  103.37618
Iteration 13:  log likelihood =  103.41012
Iteration 14:  log likelihood =  103.43741
Iteration 15:  log likelihood =  103.44297
Iteration 16:  log likelihood =  103.45406
Iteration 17:  log likelihood =  103.45545
Iteration 18:  log likelihood =  103.45839
Iteration 19:  log likelihood =  103.45926
Iteration 20:  log likelihood =  103.45979
Iteration 21:  log likelihood =  103.46021
Iteration 22:  log likelihood =  103.46047
Iteration 23:  log likelihood =  103.46061
Iteration 24:  log likelihood =  103.46075
Iteration 25:  log likelihood =  103.46078
Iteration 26:  log likelihood =  103.46085
Iteration 27:  log likelihood =  103.46086
Iteration 28:  log likelihood =  103.46087
Iteration 29:  log likelihood =  103.46088

Stoc. frontier normal/half-normal model           Number of obs   =         60
                                                  Wald chi2(8)    =   4.44e+10
Log likelihood =  103.46088                       Prob > chi2     =     0.0000

------------------------------------------------------------------------------
        YCWP |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        X1DC |    .286203   .0000167   1.7e+04   0.000     .2861703    .2862358
       X2NDC |   .1459129   .0000122   1.2e+04   0.000      .145889    .1459367
     X3DCONS |   .0637203   8.27e-07   7.7e+04   0.000     .0637187    .0637219
    X4NDCONS |   .1854007   2.52e-06   7.4e+04   0.000     .1853957    .1854056
       X5QOW |   .0605708   4.93e-06   1.2e+04   0.000     .0605612    .0605805
        X6OM |  -.0131893   6.78e-07  -1.9e+04   0.000    -.0131906    -.013188
        X8RM |  -.0353976   2.51e-06  -1.4e+04   0.000    -.0354025   -.0353927
       X9CCR |   .0182004   2.26e-06   8064.77   0.000      .018196    .0182048
       _cons |   6.256544   .0001072   5.8e+04   0.000     6.256334    6.256754
-------------+----------------------------------------------------------------
    /lnsig2v |  -38.64462   197.0124     -0.20   0.844    -424.7818    347.4926
    /lnsig2u |  -4.900279   .1825742    -26.84   0.000    -5.258118    -4.54244
-------------+----------------------------------------------------------------
     sigma_v |   4.06e-09   4.00e-07                      5.75e-93    2.86e+75
     sigma_u |   .0862816   .0078764                      .0721463    .1031862
      sigma2 |   .0074445   .0013592                      .0047806    .0101084
      lambda |   2.13e+07   .0078764                      2.13e+07    2.13e+07
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 0.00   Prob>=chibar2 = 1.000
```

➢ The output of 'STATA' for NWSDB in 2010

```
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Notes:
      1.  (/v# option or -set maxvar-) 5000 maximum variables

. import excel "C:\Users\UDITHA\Desktop\2010-STATA for NWSDB.xlsx", sheet("2010") firstrow

. frontier YCWP X1DC X2NDC X3DCONS X4NDCONS X5QOW X6OM X8RM X9CCR

Iteration 0:   log likelihood =  246.79801
Iteration 1:   log likelihood =  247.29881
Iteration 2:   log likelihood =  247.30142
Iteration 3:   log likelihood =  247.30143

Stoc. frontier normal/half-normal model           Number of obs   =        252
                                                  Wald chi2(8)    =   18680.82
Log likelihood =  247.30143                       Prob > chi2     =     0.0000
```

YCWP	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
X1DC	.3189712	.0631695	5.05	0.000	.1951614	.4427811
X2NDC	.0044421	.0173927	0.26	0.798	-.029647	.0385312
X3DCONS	.4613655	.0598505	7.71	0.000	.3440607	.5786704
X4NDCONS	.2278166	.0151773	15.01	0.000	.1980696	.2575635
X5QOW	-.056031	.0185013	-3.03	0.002	-.0922928	-.0197692
X6OM	-.0329433	.0318146	-1.04	0.300	-.0952987	.0294122
X8RM	.0107514	.0072695	1.48	0.139	-.0034966	.0249994
X9CCR	.0202306	.0067053	3.02	0.003	.0070883	.0333728
_cons	1.838885	.1623141	11.33	0.000	1.520755	2.157015
/lnsig2v	-5.311783	.2769033	-19.18	0.000	-5.854504	-4.769063
/lnsig2u	-4.674515	.4331625	-10.79	0.000	-5.523498	-3.825532
sigma_v	.0702362	.0097243			.053544	.0921321
sigma_u	.0965922	.0209201			.0631812	.1476714
sigma2	.0142632	.0029579			.0084659	.0200605
lambda	1.375248	.0296724			1.317092	1.433405

```
Likelihood-ratio test of sigma_u=0: chibar2(01) = 3.40    Prob>=chibar2 = 0.033
```

➢ The output of 'STATA' for NWSDB in 2011

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Notes:
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. import excel "C:\Users\UDITHA\Desktop\2011- STATA for NWSDB.xlsx", sheet("Sheet1") firstrow

. frontier YCWP X1DC X2NDC X3DCONS X4NDCONS X5QOW X6OM X8RM X9CCR

Iteration 0:   log likelihood =  254.91413  (not concave)
Iteration 1:   log likelihood =  255.01762
Iteration 2:   log likelihood =  255.15128
Iteration 3:   log likelihood =  255.45354
Iteration 4:   log likelihood =   255.6907
Iteration 5:   log likelihood =   255.6944
Iteration 6:   log likelihood =  255.69443
Iteration 7:   log likelihood =  255.69443

Stoc. frontier normal/half-normal model         Number of obs   =        252
                                                Wald chi2(8)    =   19197.43
Log likelihood =  255.69443                     Prob > chi2     =     0.0000
```

YCWP	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
X1DC	.212842	.050897	4.18	0.000	.1130857	.3125984
X2NDC	-.0438802	.0214891	-2.04	0.041	-.0859981	-.0017623
X3DCONS	.5661307	.0494509	11.45	0.000	.4692088	.6630526
X4NDCONS	.2582448	.0138268	18.68	0.000	.2311447	.2853448
X5QOW	.0061152	.0184711	0.33	0.741	-.0300875	.0423178
X6OM	-.0746355	.0274071	-2.72	0.006	-.1283525	-.0209185
X8RM	.014432	.0077565	1.86	0.063	-.0007705	.0296345
X9CCR	.0171433	.0063282	2.71	0.007	.0047402	.0295463
_cons	1.559731	.1659081	9.40	0.000	1.234557	1.884905
/lnsig2v	-5.563559	.3327566	-16.72	0.000	-6.21575	-4.911368
/lnsig2u	-4.505037	.3705893	-12.16	0.000	-5.231378	-3.778695
sigma_v	.0619282	.0103035			.0446958	.0858045
sigma_u	.1051341	.0194808			.0731174	.1511704
sigma2	.0148883	.0030595			.0088917	.0208849
lambda	1.697678	.0288623			1.641109	1.754247

```
Likelihood-ratio test of sigma_u=0: chibar2(01) = 1.72   Prob>=chibar2 = 0.095
```

➢ The output of 'STATA' for NWSDB in 2012

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Notes:
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. frontier YCWP X1DC X2NDC X3DCONS X4NDCONS X5QOW X6OM X8RM X9CCR

Iteration 0:   log likelihood =  190.69522
Iteration 1:   log likelihood =  191.02023
Iteration 2:   log likelihood =  191.24639
Iteration 3:   log likelihood =  191.24928
Iteration 4:   log likelihood =  191.24932
Iteration 5:   log likelihood =  191.24932

Stoc. frontier normal/half-normal model           Number of obs   =        252
                                                  Wald chi2(8)    =   13616.80
Log likelihood =  191.24932                       Prob > chi2     =     0.0000
```

YCWP	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
X1DC	.6744879	.0323543	20.85	0.000	.6110746	.7379012
X2NDC	.1925132	.0354762	5.43	0.000	.1229812	.2620453
X3DCONS	.1233047	.0192335	6.41	0.000	.0856076	.1610017
X4NDCONS	.1831015	.017689	10.35	0.000	.1484318	.2177712
X5QOW	-.1163029	.0293764	-3.96	0.000	-.1738796	-.0587263
X6OM	-.1487253	.0343703	-4.33	0.000	-.2160898	-.0813607
X8RM	-.0027344	.0061591	-0.44	0.657	-.0148061	.0093373
X9CCR	.0050181	.0074056	0.68	0.498	-.0094966	.0195329
_cons	2.679551	.1502215	17.84	0.000	2.385122	2.97398
/lnsig2v	-4.998607	.3937099	-12.70	0.000	-5.770264	-4.22695
/lnsig2u	-4.052895	.4718176	-8.59	0.000	-4.977641	-3.12815
sigma_v	.0821422	.0161701			.0558474	.1208174
sigma_u	.1318029	.0310935			.0830078	.2092815
sigma2	.0241193	.0058833			.0125882	.0356505
lambda	1.60457	.0462954			1.513833	1.695307

```
Likelihood-ratio test of sigma_u=0: chibar2(01) = 2.21   Prob>=chibar2 = 0.069
```

➢ The output of ‘STATA’ for NWSDB in 2013

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Notes:
      1.  (/v# option or -set maxvar-) 5000 maximum variables

. import excel "C:\Users\UDITHA\Desktop\2013-STATA for NWSDB.xlsx", sheet("Sheet1") firstrow

. frontier YCWP X1DC X2NDC X3DCONS X4NDCONS X5QOW X6OM X8RM X9CCR

Iteration 0:   log likelihood =  276.48413
Iteration 1:   log likelihood =  277.37047
Iteration 2:   log likelihood =  277.73322
Iteration 3:   log likelihood =  277.73512
Iteration 4:   log likelihood =  277.73512

Stoc. frontier normal/half-normal model          Number of obs    =       252
                                                 Wald chi2(8)     =  24083.98
Log likelihood =  277.73512                      Prob > chi2      =    0.0000
```


YCWP	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
X1DC	-.0161162	.0277922	-0.58	0.562	-.0705879	.0383555
X2NDC	.0446158	.023951	1.86	0.062	-.0023273	.091559
X3DCONS	.8205583	.0274934	29.85	0.000	.7666721	.8744444
X4NDCONS	.1616731	.0102819	15.72	0.000	.1415208	.1818253
X5QOW	-.0669573	.0170134	-3.94	0.000	-.1003029	-.0336118
X6OM	.0548884	.0245605	2.23	0.025	.0067507	.1030262
X8RM	-.0145806	.0036086	-4.04	0.000	-.0216533	-.0075079
X9CCR	.0106471	.0045884	2.32	0.020	.001654	.0196401
_cons	.9142577	.1360938	6.72	0.000	.6475187	1.180997
/lnsig2v	-5.990218	.3248857	-18.44	0.000	-6.626982	-5.353454
/lnsig2u	-4.459726	.251707	-17.72	0.000	-4.953063	-3.96639
sigma_v	.0500312	.0081272			.0363889	.0687879
sigma_u	.1075431	.0135347			.0840342	.1376288
sigma2	.0140686	.0023219			.0095179	.0186194
lambda	2.149523	.0205728			2.109201	2.189845

```
Likelihood-ratio test of sigma_u=0: chibar2(01) = 6.94   Prob>=chibar2 = 0.004
```

- The output of ‘STATA’ for NWSDB in 2014

```
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Notes:
      1.  (/v# option or -set maxvar-) 5000 maximum variables

. import excel "C:\Users\UDITHA\Desktop\2014-STATA for NWSDB.xlsx", sheet("LN data 2014") firstrow

. frontier YCWP X1DC X2NDC X3DCONS X4NDCONS X5QOW X6OM X8RM X9CCR

Iteration 0:   log likelihood =  292.02321  (not concave)
Iteration 1:   log likelihood =  292.68268
Iteration 2:   log likelihood =   293.5541
Iteration 3:   log likelihood =  293.63042
Iteration 4:   log likelihood =  293.63055
Iteration 5:   log likelihood =  293.63055

Stoc. frontier normal/half-normal model         Number of obs      =       252
                                                Wald chi2(8)       =  25621.03
Log likelihood =  293.63055                     Prob > chi2        =    0.0000
```

YCWP	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
X1DC	.0105879	.0462749	0.23	0.819	-.0801093	.1012851
X2NDC	.017056	.0184002	0.93	0.354	-.0190077	.0531197
X3DCONS	.7737405	.042655	18.14	0.000	.6901382	.8573427
X4NDCONS	.2340334	.0130563	17.93	0.000	.2084436	.2596232
X5QOW	-.0368733	.015678	-2.35	0.019	-.0676017	-.0061449
X6OM	-.0232761	.0182174	-1.28	0.201	-.0589816	.0124294
X8RM	-.0058525	.0030556	-1.92	0.055	-.0118414	.0001364
X9CCR	.0053761	.0047144	1.14	0.254	-.003864	.0146163
_cons	.8518214	.1229056	6.93	0.000	.6109309	1.092712
/lnsig2v	-6.343524	.3799229	-16.70	0.000	-7.088159	-5.598889
/lnsig2u	-4.445391	.2271876	-19.57	0.000	-4.890671	-4.000112
sigma_v	.0419297	.007965			.0288952	.0608439
sigma_u	.1083167	.0123041			.086697	.1353277
sigma2	.0134906	.0021769			.009224	.0177572
lambda	2.583297	.0192258			2.545615	2.620978

```
Likelihood-ratio test of sigma_u=0: chibar2(01) = 4.83   Prob>=chibar2 = 0.014
```

Annex 02. Regional Monthly Observations

Data for Regional Manager's Centre includes eleven variables. Each variable is included Sixty Monthly observations for the period from 2010 to 2014. This annexe is included monthly observations for 21 Regional Manager's Centres.

NWSDB- TEC-North Monthly Input & Output Data												
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	3,193,240	118,089	7,115	2,114,123	494,294	77	300	584,682	1,024	960	710	1,511
2	3,178,713	118,310	7,098	2,198,956	401,628	69	298	580,115	2,245	1,928	250	1,370
3	3,171,368	118,570	7,466	2,257,679	346,071	74	298	574,969	3,016	3,138	311	1,169
4	3,187,963	118,875	7,214	2,389,377	225,123	94	298	577,021	3,550	3,980	359	1,199
5	3,201,877	119,221	7,214	2,325,332	302,169	61	353	578,579	4,282	4,733	180	1,305
6	3,200,362	119,551	7,297	2,145,732	482,935	61	299	577,025	5,742	5,953	3	1,141
7	3,184,598	119,906	7,336	2,026,027	600,890	75	299	571,954	6,413	7,177	1	950
8	3,157,023	120,276	7,688	2,189,003	450,414	79	299	560,687	7,359	8,395	2	909
9	3,151,423	120,285	7,401	2,199,863	456,970	93	297	552,760	8,179	9,427	3	830
10	3,173,076	120,705	7,452	2,187,666	475,653	49	297	551,798	9,017	10,439	1	878
11	3,213,633	121,228	7,461	2,178,694	488,625	62	297	557,565	9,816	11,513	2	930
12	3,212,950	121,448	7,506	2,054,668	604,401	73	296	557,126	10,545	12,659	2	982
2011- 1	3,228,936	121,799	7,531	2,189,167	480,069	64	296	559,575	869	1,095	2	894
2	3,215,796	122,168	7,547	2,220,397	455,422	80	296	557,297	1,326	2,014	3	784
3	3,249,403	122,390	7,573	2,228,583	446,487	74	299	574,494	2,251	3,081	2	774
4	3,219,642	122,748	7,629	2,382,381	294,772	39	299	542,510	2,835	3,930	11	748
5	3,229,233	123,145	2,907	2,351,164	330,156	29	299	548,001	3,669	4,843	59	825
6	3,297,700	128,260	7,726	2,353,904	346,749	52	302	596,884	4,338	5,877	109	841
7	3,351,192	123,860	7,744	2,354,681	379,805	55	302	616,619	4,732	6,893	98	725
8	3,459,243	124,099	7,811	2,271,018	470,968	63	302	717,101	5,750	7,861	93	863
9	3,552,745	124,686	7,966	2,275,334	470,332	75	307	807,539	6,679	8,818	136	918
10	3,620,023	125,027	7,994	2,341,797	420,370	70	307	857,945	7,576	9,694	138	870
11	3,660,266	125,497	8,043	2,339,536	438,631	56	307	882,124	8,165	10,535	148	818
12	3,719,581	125,757	8,076	2,192,668	601,081	84	305	925,804	8,910	11,428	168	847
2012 -1	3,772,109	126,095	8,098	2,335,957	472,043	70	305	781,958	968	999	338	798
2	3,790,161	126,457	8,111	2,441,927	387,740	121	305	812,990	1,764	1,782	120	808
3	3,784,649	126,792	8,205	2,404,946	456,052	83	312	832,623	2,787	2,494	159	240
4	3,794,613	127,085	8,237	2,508,580	356,918	65	312	857,962	3,725	3,173	212	407
5	3,825,995	127,553	8,257	2,620,986	260,095	78	312	888,013	4,650	4,142	245	454
6	3,789,912	128,020	8,337	2,580,515	332,232	58	319	894,040	5,815	4,907	259	419
7	3,771,938	128,324	8,435	2,546,205	387,876	80	319	899,984	6,914	5,731	136	375
8	3,740,895	128,963	8,454	2,403,233	556,681	71	319	892,203	8,394	6,590	61	345
9	3,704,606	129,545	8,460	2,202,841	769,323	66	305	874,657	9,757	7,437	97	342
10	3,698,089	129,876	8,488	2,242,841	717,157	95	305	861,655	11,096	8,291	123	313
11	3,718,257	130,250	8,533	2,289,619	665,712	82	305	855,199	11,941	9,223	217	312
12	3,739,652	130,679	8,577	2,314,562	650,185	77	308	847,405	12,870	10,023	272	424
2013 -1	3,768,498	131,020	8,622	2,326,678	637,902	90	308	840,752	1,209	782	45	450
2	3,847,405	131,358	8,666	2,347,341	618,906	78	308	850,277	2,428	1,529	51	421
3	3,895,611	131,698	8,711	2,357,876	598,791	88	311	860,151	3,601	2,260	107	562
4	4,001,267	132,030	8,755	2,373,072	586,761	98	311	889,482	4,336	2,762	172	607
5	4,037,735	132,365	8,800	2,374,478	599,355	72	311	904,049	5,040	3,547	385	542
6	4,124,097	132,680	8,844	2,407,276	566,724	78	314	941,119	6,641	4,390	362	947
7	4,174,213	133,005	8,895	2,435,198	511,232	84	314	979,270	7,843	5,179	302	295
8	4,211,491	133,404	8,911	2,411,489	504,024	95	314	1,024,235	8,792	5,950	353	452
9	4,289,877	133,726	8,996	2,491,982	424,531	68	306	1,088,342	9,744	6,759	204	467
10	4,331,691	134,077	9,036	2,431,619	514,810	77	306	1,142,700	10,845	7,537	15	455
11	4,357,018	134,354	9,070	2,479,448	484,231	84	306	1,190,773	11,741	8,190	46	444
12	4,375,153	134,713	9,128	2,384,315	599,281	69	313	1,234,668	12,754	8,908	60	444
2014 -1	4,399,831	134,882	9,194	2,636,865	354,647	97	313	1,279,471	936	659	131	529
2	4,406,400	135,285	9,266	2,630,652	386,611	85	313	1,311,345	1,932	1,347	135	605
3	4,425,544	135,627	9,335	2,551,349	483,580	88	313	1,342,267	2,962	2,241	141	635
4	4,419,012	136,012	11,237	2,672,786	374,393	72	313	1,357,962	3,856	2,941	279	611
5	4,400,535	136,380	9,459	2,612,099	441,330	77	313	1,366,806	4,912	3,907	224	665
6	4,401,980	136,903	9,462	2,524,056	537,873	79	316	1,376,059	5,814	4,783	290	542
7	4,437,207	137,387	9,465	2,549,487	540,429	82	316	1,390,177	6,930	5,736	458	422
8	4,487,094	137,765	9,527	2,714,086	411,415	88	316	1,404,012	7,627	6,612	356	411
9	4,491,629	138,223	9,579	2,716,762	442,322	78	318	1,396,447	8,627	7,516	344	476
10	4,506,509	138,827	9,657	2,600,263	581,737	68	318	1,391,610	9,645	8,367	298	436
11	4,534,035	139,018	9,711	2,403,332	795,834	77	318	1,390,135	10,647	9,228	404	369
12	4,535,073	139,340	9,804	2,315,295	878,955	95	327	1,382,290	11,759	10,089	448	358

OUTPUT

Y = CWP -Clear water Production (Volume m3/month)

INPUTs

X_1 = DC - Domestic Connections (Numbers/month), X_2 = NDC - Non Domestic Connections (Numbers/month), X_3 = DCONS- Domestic Consumption (Volume m3/month)
X_4 = NDCONS - Non Domestic Consumption (Volume m3/month), X_5 = QOW- Quality of Water (Number of sample tested/month)
X_6 = O&M - O&M Staff (Numbers/month), X_7 = NRW- Non Revenue Water volume (Volume m3/month)
X_8 = RM - Rectification of Meters (Numbers/month)
X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

OUTPUT

NWSDB- AKKARAIPATTU Monthly Input & Output Data											
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	425,626	31,398	1,106	359,666	111,661	120	269	65,972	68	187	102	791
2	392,367	32,052	1,109	325,757	45,665	111	269	41,669	289	260	115	900
3	458,409	32,577	1,557	355,187	44,245	131	269	52,396	277	260	103	727
4	590,372	33,012	1,132	429,137	60,527	78	269	77,988	114	210	105	807
5	600,598	33,332	1,144	372,780	86,990	80	269	94,294	256	135	138	761
6	550,575	33,847	1,180	392,331	48,259	65	291	90,735	380	140	71	710
7	608,546	34,641	1,208	414,742	48,887	141	291	107,773	250	118	55	657
8	625,076	35,222	1,235	446,572	58,948	130	291	112,014	287	165	89	601
9	591,394	35,732	1,321	426,184	48,963	126	282	107,220	298	180	71	564
10	634,044	38,455	1,327	443,921	53,693	92	282	117,425	303	207	95	512
11	600,519	38,787	1,330	419,425	43,891	101	282	113,798	225	165	118	971
12	558,703	38,805	1,336	384,076	40,091	65	281	108,277	160	130	97	1,314
2011- 1	523,057	38,916	1,350	356,469	37,599	65	281	129,195	36	33	118	1,092
2	486,607	39,135	1,352	364,680	38,355	52	281	83,696	26	37	109	1,185
3	509,625	39,171	1,368	388,629	38,723	54	279	82,050	60	32	132	1,190
4	596,941	39,677	1,376	445,681	46,300	38	279	105,062	107	37	106	1,266
5	644,181	39,927	1,390	460,140	66,222	42	279	119173	59	52	80	1,300
6	636,127	40,104	1,415	447,445	54,636	55	279	134,223	94	37	132	1,216
7	612,912	40,572	1,446	438,413	47,291	45	279	127,486	24	41	142	1,271
8	634,357	41,371	1,471	466,590	53,244	48	279	114,819	102	44	149	1,329
9	607,441	42,041	1,529	477,161	46,881	52	272	83,219	67	67	140	1,470
10	631,405	42,439	1,546	471,816	52,298	58	272	107,339	143	42	179	1,455
11	554,494	43,214	1,560	479,719	48,588	65	272	26,061	70	45	177	1,084
12	532,049	43,814	1,596	439,711	48,083	73	269	44,160	118	60	157	966
2012 -1	600,044	44,056	1,629	434,110	42,052	67	269	97,867	137	64	194	850
2	550,095	44,620	1,652	442,410	44,696	80	269	87,355	312	109	132	807
3	673,244	44,887	1,668	469,915	47,951	75	267	111,287	423	148	145	830
4	688,720	45,179	1,700	519,679	55,339	65	267	113,226	469	191	187	666
5	727,314	45,791	1,726	545,747	58,724	45	267	118,698	788	230	209	585
6	713,355	46,550	1,731	566,346	63,298	56	266	110,499	962	268	241	453
7	729,190	46,917	1,757	555,196	59,043	46	266	110,035	1,063	308	39	49
8	727,902	47,177	1,819	555,516	57,147	58	266	108,603	1,224	343	37	4
9	694,642	47,732	1,867	567,793	53,647	63	266	101,557	1,390	379	22	7
10	714,757	47,980	1,882	522,690	82,140	46	266	103,640	1,505	423	18	7
11	657,670	48,892	1,896	504,342	40,105	46	266	101,281	1,688	464	12	4
12	635,421	49,074	1,909	463,053	52,468	65	267	102,557	1,779	503	7	2
2013 -1	602,039	49,302	1,923	481,067	18,396	73	267	95,544	184	40	7	6
2	577,101	49,529	1,937	496,663	13,768	55	267	91,528	365	77	10	5
3	653,992	49,757	1,950	510,391	11,709	58	265	102,088	434	114	7	7
4	690,241	49,984	1,964	520,750	44,705	58	265	108,644	525	145	7	2
5	717,998	50,212	1,978	523,919	51,213	92	265	114,951	828	174	12	2
6	709,758	50,439	1,991	523,221	79,850	78	269	115,691	1,167	242	7	2
7	792,599	50,667	2,021	522,290	116,694	57	269	131,968	1,411	252	9	2
8	782,627	50,894	2,073	607,167	71,271	61	269	128,351	1,629	277	10	3
9	805,572	52,089	2,127	605,836	74,852	67	271	135,336	1,939	299	7	2
10	771,826	52,946	2,141	606,481	73,439	72	271	127,120	2,099	311	7	2
11	769,391	53,336	2,158	593,267	62,141	80	271	125,180	2,350	330	12	2
12	699,805	53,701	2,159	546,105	58,096	60	271	110,989	2,540	366	7	2
2014 -1	699,524	53,931	2,173	518,330	57,421	74	271	111,434	250	72	7	9
2	717,333	53,934	2,186	515,772	63,392	65	271	118,216	278	68	7	17
3	796,552	54,180	2,185	563,858	71,703	84	259	131,829	325	83	5	14
4	755,704	54,474	2,216	611,245	72,344	58	259	119,704	270	80	7	3
5	797,276	54,483	2,231	652,832	75,567	58	259	118,714	234	71	56	15
6	824,343	54,843	2,245	672,708	74,730	69	258	118,541	200	89	9	6
7	833,395	55,023	2,275	672,907	78,392	57	258	112,925	365	90	12	9
8	910,652	55,216	2,323	663,027	77,298	75	258	128,129	250	72	15	18
9	807,168	55,826	2,338	641,498	81,104	78	257	110,017	180	78	15	4
10	889,880	56,736	2,345	642,835	74,334	85	257	127,431	130	114	18	2
11	799,908	57,215	2,354	591,877	71,115	85	257	116,067	87	115	18	2
12	788,712	57,296	2,355	561,343	66,369	90	268	118,780	63	112	18	2

Y = CWP -Clear water Production (Volume m3/month)
<u>INPUTs</u>

X1 = DC - Domestic Connections (Numbers/month)
X2 = NDC - Non Domestic Connections (Numbers/month)
X3 = DCONS- Domestic Consumption (Volume m3/month)
X4 = NDCONS - Non Domestic Consumption (Volume m3/month

X5 = QOW- Quality of Water (Number of sample tested/month)
X6 = O&M - O&M Staff (Numbers/month)
X7 = NRW- Non Revenue Water volume (Volume m3/month)
X8 = RM - Rectification of Meters (Numbers/month)
X9 = CCR - Consumer Complaints Received (Numbers/month)
X10 = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- AMPARA Monthly Input & Output Data

Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	550,920	22,168	1,603	288,157	91,783	111	286	171,006	101	190	601	5,927
2	503,456	22,212	1,610	280,209	86,899	111	286	146,757	194	399	760	675
3	557,771	22,287	1,727	297,734	89,972	115	236	165,156	340	726	1,021	2,264
4	572,005	22,399	1,623	359,298	92,582	66	236	156,501	444	890	1,047	721
5	574,669	22,522	1,628	327,206	93,395	66	236	156,540	985	1,180	819	618
6	591,494	22,644	1,662	335,608	96,279	53	245	160,886	1,371	1,441	762	584
7	611,622	22,865	1,670	340,778	97,602	141	245	167,401	1,627	1,661	680	541
8	620,055	23,015	1,726	349,821	101,962	142	245	169,523	1,835	1,866	649	508
9	573,104	23,030	1,704	353,196	83,590	126	254	154,394	2,017	2,077	687	434
10	571,265	23,193	1,722	328,146	95,882	80	254	153,270	2,192	2,270	690	400
11	538,074	23,472	1,734	327,788	93,446	101	254	141,998	2,385	2,534	700	387
12	505,056	23,637	1,343	304,590	91,490	38	201	131,466	2,631	2,753	651	376
2011- 1	397,713	18,295	1,346	238,686	63,175	38	201	94,338	189	28	477	776
2	412,716	18,482	1,342	239,345	62,321	47	201	102,725	344	127	427	330
3	438,505	18,544	1,350	251,581	63,260	54	207	113,485	471	266	390	373
4	485,524	18,593	1,355	294,027	70,266	42	207	123,857	576	451	380	391
5	499,594	18,639	1,357	302,449	70,440	42	207	126,897	711	663	404	406
6	515,703	18,677	1,365	324,854	79,960	45	189	126,708	845	859	369	354
7	520,236	18,790	1,372	316,040	82,767	45	189	126,573	883	1,075	459	326
8	505,990	18,995	1,387	313,131	81,246	46	189	121,185	988	1,288	530	354
9	492,634	19,162	1,413	301,295	79,634	46	191	117,050	1,082	1,501	588	332
10	498,334	19,402	1,419	307,369	76,028	46	191	117,457	1,289	1,721	608	353
11	481,372	19,633	1,443	295,569	75,088	46	191	113,122	1,479	1,920	540	322
12	474,777	19,697	1,452	274,402	75,333	46	191	112,665	1,559	2,095	510	368
2012 -1	470,324	19,934	1,459	277,797	74,562	44	191	114,195	143	255	531	337
2	468,115	19,808	1,467	285,291	74,439	44	191	112,348	428	248	470	340
3	484,518	19,875	1,473	295,565	74,451	42	193	114,637	657	390	246	309
4	517,310	19,946	1,485	321,418	77,895	42	193	121,464	778	284	238	495
5	534,767	19,989	1,490	335,838	76,995	45	193	124,387	925	306	238	308
6	571,480	20,091	1,503	360,600	96,465	45	199	132,012	1,017	319	266	293
7	571,865	20,199	1,512	348,925	92,506	46	199	131,815	1,074	312	340	330
8	556,723	20,611	1,530	363,733	86,536	46	199	126,821	1,194	368	388	338
9	544,520	21,094	1,281	354,228	88,221	46	191	122,136	1,352	357	421	587
10	546,533	21,745	1,550	355,300	82,409	46	191	121,112	1,550	346	445	390
11	508,079	21,911	1,565	355,980	53,591	46	191	111,117	1,760	204	519	308
12	489,949	22,184	1,575	357,229	27,222	44	200	105,339	1,898	321	35	142
2013 -1	477,491	22,345	1,590	358,980	10,893	44	200	101,753	244	247	467	370
2	448,332	22,540	1,598	360,390	8,097	58	200	93,791	382	429	447	355
3	527,296	22,820	1,608	361,470	22,301	58	199	111,998	478	597	442	575
4	550,902	23,067	1,615	362,549	73,076	58	199	116,185	584	787	529	351
5	582,294	23,114	1,624	365,067	74,242	84	199	123,796	856	969	497	344
6	557,597	23,320	1,632	366,090	68,439	58	201	119,549	1,008	1,210	511	328
7	582,262	23,655	1,686	367,066	75,772	58	201	125,477	1,149	1,456	562	320
8	578,734	23,858	1,653	367,875	90,773	61	201	125,527	1,376	1,678	563	365
9	560,689	24,175	1,669	372,708	91,607	57	199	120,772	1,571	1,944	545	367
10	591,552	24,395	1,673	382,973	95,379	65	199	126,947	1,770	2,189	528	344
11	534,037	24,712	1,720	350,353	92,414	60	199	113,536	1,981	2,417	426	372
12	480,023	25,026	2,776	321,434	80,641	60	199	100,181	2,220	2,589	397	368
2014 -1	501,135	25,104	1,766	313,351	91,065	62	199	103,384	649	172	321	361
2	478,846	25,257	1,792	313,404	85,461	58	199	98,307	378	65	241	369
3	570,844	27,335	1,796	342,313	89,135	84	224	116,053	308	63	370	503
4	625,286	28,145	1,843	405,117	97,617	58	224	126,433	241	69	390	547
5	645,380	28,360	1,845	432,126	88,084	58	224	127,527	510	71	276	436
6	646,101	29,015	1,871	427,132	105,734	61	224	125,085	490	70	308	539
7	642,825	29,351	1,880	429,005	100,057	57	224	120,915	414	68	282	435
8	655,957	29,770	1,885	452,715	102,426	65	224	120,237	380	72	419	433
9	632,243	29,943	1,880	432,376	102,518	60	226	114,752	280	68	306	518
10	600,271	30,121	1,885	416,920	92,714	60	226	106,908	1,614	180	321	464
11	575,381	30,282	1,888	396,170	92,453	58	226	101,497	714	140	273	535
12	563,324	30,384	1,899	360,667	85,680	62	236	101,286	758	68	228	498

OUTPUT
Y = CWP -Clear water Production (Volume m3/month)
INPUTs
X1 = DC - Domestic Connections (Numbers/month)
X2 = NDC - Non Domestic Connections (Numbers/month)
X3 = DCONS- Domestic Consumption (Volume m3/month)
X4 = NDCONS - Non Domestic Consumption (Volume m3/month)
X5 = QOW- Quality of Water (Number of sample tested/month)
X6 = O&M - O&M Staff (Numbers/month)
X7 = NRW- Non Revenue Water volume (Volume m3/month)
X8 = RM - Rectification of Meters (Numbers/month)
X9 = CCR - Consumer Complaints Received (Numbers/month)
X10 = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- ANURADAPURA Monthly Input & Output Data											
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	1,243,000	50,358	5,682	605,551	371,316	55	333	266,126	123	58	128	360
2	1,263,000	50,933	5,695	650,613	362,184	56	333	260,178	246	122	171	367
3	1,649,000	51,185	5,881	750,524	382,249	65	333	409,777	548	177	244	296
4	1,281,000	51,337	5,743	856,302	388,914	60	333	251,717	745	226	281	968
5	1,446,000	51,799	5,749	768,759	356,273	63	333	291,947	973	280	356	247
6	1,405,000	52,479	5,805	840,730	396,434	105	299	264,000	1,038	339	344	248
7	1,535,000	53,711	5,862	893,278	403,097	72	299	280,598	1,206	397	403	332
8	1,489,000	53,949	5,904	844,658	407,258	98	299	267,573	1,462	445	409	1,026
9	1,424,000	54,498	5,972	861,409	408,987	105	294	244,501	1,783	486	308	485
10	1,453,000	55,597	6,008	802,396	394,025	71	294	250,207	2,090	527	205	481
11	1,342,000	56,267	6,039	806,862	383,734	91	294	224,248	2,304	577	132	487
12	1,263,000	56,540	6,088	694,177	381,823	82	294	209,153	2,539	631	258	547
2011- 1	1,308,000	56,990	6,102	689,385	383,361	89	294	234,132	211	104	261	577
2	1,261,000	57,354	6,122	730,714	400,193	82	294	179,062	389	154	283	2,353
3	1,536,000	57,597	6,135	753,590	389,902	89	297	276,480	665	217	288	542
4	1,503,000	57,848	6,166	881,073	418,257	85	297	255,510	781	263	300	522
5	1,653,000	58,184	6,194	893,266	416,872	100	297	297,540	1,131	322	379	580
6	1,696,000	58,483	6,232	900,015	428,870	97	296	317,152	1,509	369	430	611
7	1,692,000	58,923	6,273	944,350	439,434	96	296	314,712	1,851	420	406	615
8	1,773,000	59,316	6,331	945,378	447,613	102	296	336,870	2,132	464	439	585
9	1,750,000	59,703	6,390	990,818	466,113	34	294	327,250	2,429	520	392	559
10	1,625,000	60,022	6,465	983,608	449,428	93	294	292,500	2,717	583	270	552
11	1,447,000	60,352	6,538	826,289	377,372	92	294	259,013	3,204	635	212	555
12	1,496,000	60,829	6,567	757,850	392,032	133	302	273,768	3,475	683	228	586
2012 -1	1,592,000	62,008	6,604	786,677	381,972	129	302	303,117	356	54	226	608
2	1,518,000	61,651	6,661	830,903	422,709	126	302	295,706	604	114	213	617
3	1,740,000	62,022	6,736	882,521	421,870	85	302	339,300	1,011	218	183	591
4	1,661,000	62,685	6,812	976,118	419,138	73	302	326,553	1,285	277	249	570
5	1,874,000	64,375	7,007	999,284	426,440	97	302	374,238	1,581	320	300	497
6	1,846,000	66,404	7,064	1,129,237	452,052	96	302	356,463	2,050	367	341	515
7	1,959,000	68,100	7,180	1,076,137	453,093	105	302	385,139	2,527	421	35	524
8	1,948,420	68,972	7,267	1,146,254	442,704	72	302	377,799	2,859	472	439	528
9	1,890,166	69,290	7,326	1,195,601	428,144	93	336	361,589	3,351	535	581	1,760
10	1,679,341	69,987	7,355	1,018,220	484,212	92	336	319,075	3,997	584	617	1,513
11	1,859,692	71,481	7,428	899,794	427,645	133	336	371,938	4,578	638	604	1,585
12	1,712,704	72,867	7,508	879,601	397,074	129	365	346,309	4,975	692	562	1,637
2013 -1	1,584,692	73,218	7,680	915,015	308,252	138	365	315,988	2,100	518	227	1,289
2	1,497,950	73,603	7,720	940,120	325,968	153	365	296,594	2,090	527	202	1,452
3	1,776,940	73,890	7,784	960,148	321,965	152	341	356,276	1,783	486	315	1,223
4	1,847,841	74,270	7,805	978,768	533,825	172	341	373,079	1,038	339	352	652
5	1,942,249	74,565	7,944	975,045	484,031	180	341	394,082	1,206	397	443	644
6	1,919,502	75,118	8,028	980,410	552,112	175	342	399,064	1,462	445	421	453
7	1,995,094	75,360	7,995	990,814	533,988	181	342	417,773	1,115	317	334	452
8	1,994,602	75,874	8,054	1,164,995	497,046	185	342	414,279	1,870	427	354	781
9	1,908,118	75,351	8,145	1,113,294	455,182	176	358	402,422	1,670	337	326	694
10	1,970,108	76,687	8,210	1,172,990	461,952	185	358	424,164	1,235	540	332	734
11	1,697,300	76,343	8,297	1,046,857	459,796	186	358	341,666	211	104	304	771
12	1,690,700	77,603	8,341	950,066	422,869	186	358	331,546	389	154	332	734
2014 -1	1,680,605	76,951	8,380	944,447	445,987	181	358	322,676	665	217	227	850
2	1,634,051	78,255	8,409	996,645	442,164	153	358	308,999	781	263	202	775
3	1,966,266	77,635	8,546	1,025,606	418,744	152	364	371,034	1,131	322	147	763
4	1,902,143	78,806	8,599	1,223,030	466,871	172	364	347,712	1,509	369	147	763
5	1,957,291	78,293	8,669	1,127,288	436,142	180	364	349,572	917	214	244	773
6	2,065,746	79,606	8,717	1,242,105	470,946	175	366	363,571	615	318	215	683
7	2,160,443	80,062	8,770	1,288,368	492,241	181	366	368,788	435	219	222	689
8	2,057,861	80,504	8,859	1,295,437	493,206	185	366	344,486	318	450	230	695
9	2,035,979	81,094	8,770	1,260,487	547,275	181	359	329,014	440	468	265	696
10	1,911,690	81,896	8,859	1,167,476	479,539	186	359	303,768	390	730	104	683
11	1,723,944	82,582	8,890	1,057,580	472,682	186	359	273,762	330	750	2	614
12	1,785,297	82,977	8,923	949,136	443,333	181	370	288,325	358	906	3	625

OUTPUT
Y = CWP -Clear water Production (Volume m3/month)
INPUTs
X_1 = DC - Domestic Connections (Numbers/month)
X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
X_4 = NDCONS - Non Domestic Consumption (Volume m3/month)

X_5 = QOW- Quality of Water (Number of sample tested/month)
X_6 = O&M - O&M Staff (Numbers/month)
X_7 = NRW- Non Revenue Water volume (Volume m3/month)
X_8 = RM - Rectification of Meters (Numbers/month)
X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- BANDARAWELLA Monthly Input & Output Data											
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	828,719	29,645	3,260	362,698	234,829	80	254	231,213	402	196	1,017	404
2	813,033	30,910	3,262	371,625	222,711	80	254	222,771	421	185	982	1,603
3	840,777	31,033	3,325	381,438	229,192	79	254	230,289	498	174	1,201	659
4	855,679	31,090	3,276	406,025	221,470	78	254	232,830	456	198	1,390	683
5	847,155	31,207	3,278	387,006	212,626	68	256	233,899	435	206	1,238	698
6	857,948	31,403	3,286	395,995	234,426	88	256	235,335	461	209	943	737
7	891,709	31,459	3,288	402,721	237,197	84	256	245,666	487	215	618	665
8	879,080	31,508	3,335	414,554	230,601	73	256	241,132	424	221	606	660
9	874,206	31,569	3,318	429,035	241,681	68	256	235,686	463	209	459	664
10	863,411	31,770	3,321	395,808	239,746	43	253	232,258	475	211	500	331
11	845,345	31,849	3,330	391,805	237,401	62	253	226,383	458	195	471	261
12	835,074	31,887	3,324	366,077	233,134	59	253	223,633	433	192	395	209
2011- 1	824,161	31,953	3,325	368,635	232,291	66	252	222,523	437	242	422	192
2	791,118	31,961	3,333	342,698	223,734	78	252	221,513	420	217	522	220
3	821,793	32,028	3,349	365,345	228,998	84	252	230,102	517	209	500	209
4	877,897	32,109	3,351	405,357	227,824	83	252	245,811	512	195	515	186
5	898,644	32,228	4,008	369,330	279,581	71	252	251,620	523	204	538	183
6	911,296	32,288	3,385	436,513	253,876	74	252	218,711	548	226	542	215
7	913,793	32,391	3,409	470,848	217,977	79	252	228,448	675	218	486	197
8	917,969	32,469	4,072	464,079	229,645	72	252	220,313	731	226	485	227
9	940,327	32,520	4,245	485,100	219,783	63	252	235,082	577	248	489	211
10	897,860	32,603	4,261	445,798	209,994	70	251	242,422	538	256	537	221
11	865,180	32,636	4,281	425,787	215,335	81	251	224,947	486	247	623	198
12	874,437	32,723	4,310	412,760	214,540	74	251	244,842	496	230	693	225
2012 -1	910,950	32,795	3,468	426,348	229,627	74	254	241,857	437	193	706	221
2	897,850	32,813	3,476	429,376	231,702	77	254	237,032	530	197	648	180
3	922,790	32,873	3,484	435,683	223,255	77	255	244,447	745	199	600	183
4	890,620	32,994	3,491	459,690	211,997	78	255	233,521	429	210	565	206
5	963,610	33,062	3,523	450,667	274,330	77	255	250,250	688	222	641	228
6	924,160	33,328	3,532	459,265	239,452	77	259	240,097	803	230	546	204
7	894,480	33,371	3,540	424,335	232,018	77	259	233,817	823	254	515	169
8	918,100	33,375	4,448	451,661	233,597	77	259	240,726	1,024	214	449	145
9	905,660	33,582	3,575	436,728	223,940	78	259	239,004	781	228	493	141
10	893,850	33,718	3,574	425,719	214,070	78	256	236,960	824	214	432	130
11	829,700	33,813	3,586	397,519	221,302	78	256	219,705	766	238	348	130
12	874,220	33,801	3,598	385,716	228,514	78	256	232,543	556	242	402	153
2013 -1	875,171	34,080	3,609	399,772	220,693	78	256	233,496	803	190	314	160
2	841,965	34,360	3,621	406,376	208,981	86	265	225,057	854	192	312	144
3	870,990	34,639	3,633	413,665	193,459	88	265	233,948	901	162	512	126
4	891,850	34,919	3,645	415,356	249,478	85	265	240,175	567	200	340	93
5	879,130	35,198	3,556	440,642	207,721	86	265	237,980	529	190	454	178
6	882,256	35,478	3,668	452,541	243,961	86	267	236,445	820	198	374	103
7	888,936	35,757	3,662	460,747	203,973	79	267	237,168	895	167	74	44
8	945,380	36,037	3,663	482,160	268,865	76	267	248,162	723	110	21	688
9	959,245	36,087	3,645	452,605	247,422	108	267	251,802	758	224	33	462
10	933,305	36,413	3,649	464,688	234,748	100	269	242,379	805	235	10	166
11	954,635	36,348	3,628	427,196	262,415	106	269	249,828	808	274	42	69
12	920,840	36,814	3,649	385,644	232,199	98	269	243,562	699	243	45	47
2014 -1	969,330	37,012	3,643	418,833	274,768	99	269	256,097	750	198	36	21
2	979,380	33,218	3,673	460,004	266,270	99	270	257,871	633	191	42	44
3	979,440	37,341	3,692	421,984	238,163	99	270	260,237	648	222	56	42
4	983,977	37,844	3,722	477,611	268,808	99	270	260,164	542	200	58	29
5	999,339	38,020	3,697	477,138	250,200	99	270	265,125	569	151	128	35
6	998,919	38,383	3,703	466,119	255,719	99	290	270,208	711	221	219	15
7	1,043,406	38,594	3,700	511,483	234,595	99	290	285,059	728	210	130	33
8	1,039,429	38,872	3,716	509,966	282,118	99	290	286,363	601	233	71	13
9	1,027,918	38,991	3,727	489,337	288,718	99	290	280,724	656	279	67	22
10	1,006,014	39,457	3,790	465,501	269,657	98	290	276,251	684	262	50	22
11	951,990	39,837	3,856	473,589	209,556	98	290	261,797	667	353	83	36
12	900,866	39,112	3,789	488,205	158,814	98	318	244,405	605	341	83	36

OUTPUT
Y = CWP -Clear water Production (Volume m3/month)
INPUTs
X_1 = DC - Domestic Connections (Numbers/month)
X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
X_4 = NDCONS - Non Domestic Consumption (Volume m3/month)

X_5 = QOW- Quality of Water (Number of sample tested/month)
X_6 = O&M - O&M Staff (Numbers/month)
X7 = NRW- Non Revenue Water volume (Volume m3/month)
X8 = RM - Rectification of Meters (Numbers/month)
X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- Galle Monthly Input & Output Data												
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	1,451,324	58,313	4,533	830,956	242,713	102	324	377,635	159	249	989	1,882
2	1,477,014	59,033	4,548	869,126	234,245	100	324	379,002	231	400	984	1,778
3	1,572,572	59,303	5,324	880,443	246,633	106	323	418,147	329	542	952	1,820
4	1,617,000	60,039	4,607	954,914	238,677	103	323	428,182	505	666	902	1,576
5	1,629,151	60,696	4,638	958,900	238,662	106	323	431,399	707	793	1,007	1,396
6	1,565,118	61,399	4,561	912,716	239,869	99	323	414,130	805	905	972	1,235
7	1,663,820	61,531	4,705	883,282	250,197	118	323	453,890	925	1,073	825	1,088
8	1,482,276	62,276	4,721	916,781	247,677	106	323	394,137	987	1,269	605	1,084
9	1,665,396	62,828	4,764	954,312	256,863	109	317	444,161	1,015	1,435	357	1,143
10	1,612,370	63,420	4,788	918,960	247,921	119	317	431,631	1,027	1,626	308	1,002
11	1,592,931	64,084	4,845	914,001	250,691	85	317	426,587	1,042	1,836	313	983
12	1,565,897	64,703	4,748	898,424	238,163	97	321	420,130	1,065	2,010	326	926
2011- 1	1,646,324	66,114	4,883	932,489	281,560	102	321	432,325	18	219	267	844
2	1,669,137	66,168	4,893	942,517	284,018	130	321	440,485	31	384	386	841
3	1,623,660	66,233	4,908	936,388	259,734	157	312	428,159	90	638	389	869
4	1,666,566	66,801	4,941	999,280	236,206	135	312	437,307	118	767	432	910
5	1,796,496	67,811	4,967	1,078,683	275,936	149	312	465,113	140	962	478	1,762
6	1,764,114	68,298	4,998	1,037,855	250,569	153	314	460,081	166	1,126	506	1,954
7	1,795,748	68,931	5,014	1,043,601	256,684	133	314	472,282	181	1,427	582	1,024
8	1,870,299	69,315	5,061	1,067,689	264,646	174	314	498,248	241	1,806	657	1,185
9	1,885,712	70,099	5,128	1,082,707	275,268	159	312	505,371	309	1,964	709	990
10	1,909,025	70,200	5,152	1,110,981	266,779	146	312	513,719	382	2,130	815	1,097
11	1,824,788	71,217	5,198	1,037,711	278,280	178	312	492,693	462	2,334	980	1,554
12	1,814,502	71,748	5,228	1,018,185	268,325	163	306	493,182	538	2,729	2	2,416
2012 -1	1,970,828	72,591	5,256	1,085,820	291,878	109	306	542,372	72	356	726	1,578
2	1,983,788	73,239	5,274	1,111,833	291,339	113	306	550,501	89	682	610	3,095
3	2,065,918	73,817	5,308	1,100,046	357,517	135	305	578,664	94	1,262	578	1,923
4	2,058,632	74,089	5,366	1,209,251	284,921	149	305	578,887	94	1,670	587	2,052
5	2,174,305	74,891	5,385	1,189,419	277,674	153	305	626,200	97	2,057	528	2,152
6	2,161,444	75,788	5,418	1,210,219	319,873	133	300	626,386	98	2,414	567	3,191
7	2,153,479	76,266	5,321	1,145,945	303,288	174	300	633,554	108	2,797	475	3,862
8	2,151,177	77,034	5,495	1,216,709	313,533	159	300	632,876	111	2,967	453	2,005
9	1,996,831	76,848	5,390	1,150,843	305,725	146	289	585,870	114	3,744	612	1,492
10	2,089,840	77,464	5,517	1,142,873	1,406,097	178	289	621,518	116	4,191	479	1,099
11	2,049,603	78,367	5,545	1,139,873	318,602	163	289	610,987	119	4,427	438	1,641
12	2,065,306	79,329	5,990	1,126,393	365,933	109	288	613,189	121	4,828	491	1,318
2013 -1	2,124,421	79,477	6,436	1,134,457	307,230	145	288	634,352	4	292	576	1,229
2	2,083,749	79,624	6,882	1,148,158	382,692	197	288	617,415	8	637	567	1,038
3	2,121,769	79,772	7,327	1,161,742	266,649	157	292	634,621	14	879	489	1,058
4	2,218,244	79,920	7,773	1,168,454	435,587	183	292	663,477	34	1,086	431	1,001
5	2,204,122	80,067	8,218	1,171,063	431,472	124	292	649,334	37	1,267	436	798
6	2,116,834	8,025	9,082	1,184,888	316,317	131	293	623,408	45	1,492	444	634
7	2,205,571	80,362	5,754	1,198,799	279,077	161	293	650,202	49	1,764	343	615
8	2,262,267	80,510	5,794	1,190,908	301,813	151	293	677,323	49	2,031	286	615
9	2,156,509	84,360	5,861	1,244,062	329,609	152	289	645,227	51	2,268	286	615
10	2,231,526	84,832	5,859	1,256,827	333,228	171	289	660,309	53	2,583	183	605
11	2,201,132	85,197	5,872	1,215,441	352,542	186	289	651,095	59	2,871	165	594
12	2,139,744	85,236	5,950	1,189,322	317,239	160	289	636,146	62	3,159	152	596
2014 -1	2,304,288	85,373	5,999	1,281,665	345,684	197	289	679,765	2	223	128	598
2	2,140,815	86,507	6,013	1,296,174	359,457	157	289	624,690	4	413	108	603
3	2,289,287	87,038	6,059	1,282,201	339,272	183	293	661,604	5	561	93	595
4	2,322,664	87,224	6,035	1,372,347	347,380	124	293	667,534	8	703	93	595
5	2,373,647	87,983	6,065	1,378,479	341,889	131	293	682,424	10	843	460	634
6	2,293,347	88,776	6,116	1,348,608	324,509	161	291	655,439	13	1,054	258	634
7	2,390,788	89,509	6,183	1,325,818	337,870	151	291	678,506	15	1,246	289	593
8	2,334,974	90,039	6,221	1,351,565	347,252	152	291	649,590	17	1,369	386	622
9	2,260,349	90,588	6,183	1,310,366	332,267	171	290	629,281	21	1,534	406	673
10	2,328,458	91,115	6,221	1,330,018	340,957	186	290	647,311	39	1,658	402	940
11	2,260,585	91,942	6,272	1,298,136	343,094	160	290	625,956	44	1,802	427	1,255
12	2,311,558	91,797	6,243	1,220,672	342,991	150	294	645,618	53	1,950	448	795

OUTPUT
Y = CWP -Clear water Production (Volume m3/month)

INPUTs
X_1 = DC - Domestic Connections (Numbers/month)
X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
X_4 = NCONS - Non Domestic Consumption (Volume m3/month)
X_5 = QOW- Quality of Water (Number of sample tested/month)
X_6 = O&M - O&M Staff (Numbers/month)
X_7 = NRW- Non Revenue Water volume (Volume m3/month)
X_8 = RM - Rectification of Meters (Numbers/month)
X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- GAMPHA Monthly Input & Output Data												
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	1,181,000	34,745	4,703	552,615	419,027	60	305	209,391	267	492	582	983
2	1,141,000	34,846	4,716	566,145	407,185	64	305	185,298	549	1,003	618	1,061
3	1,278,000	34,957	4,962	591,172	424,892	57	306	226,845	850	1,476	676	1,232
4	1,128,000	35,178	4,761	598,621	413,081	59	306	180,142	1,109	1,947	728	682
5	1,188,156	35,376	4,782	559,015	380,150	58	306	201,630	1,465	2,415	688	983
6	1,147,844	35,658	4,805	541,766	409,279	61	301	195,133	1,854	2,972	711	537
7	1,189,000	35,891	4,822	546,166	402,164	61	301	207,718	2,233	3,616	734	465
8	1,190,000	36,109	4,868	564,585	408,040	59	301	209,083	2,780	4,291	608	409
9	1,190,000	36,291	4,907	587,929	437,541	60	310	204,085	3,195	4,912	579	384
10	1,198,000	36,556	4,958	550,192	407,715	58	310	208,931	3,590	5,522	482	375
11	1,155,000	36,786	4,995	554,425	415,793	64	310	199,931	4,079	6,086	174	359
12	1,157,000	36,990	5,034	532,539	416,725	60	312	200,971	4,431	6,606	135	322
2011- 1	1,206,368	37,218	5,053	557,556	413,937	59	312	235,242	279	566	179	317
2	1,108,632	37,380	5,091	551,280	397,090	57	312	189,576	591	1,060	203	293
3	1,261,000	37,582	5,124	567,651	404,664	58	309	240,851	955	1,695	208	301
4	1,231,109	37,848	5,152	618,834	447,507	59	309	217,906	1,300	2,173	188	279
5	1,277,891	38,149	5,187	596,222	431,486	60	309	231,298	1,653	2,802	207	281
6	1,325,000	38,385	5,216	614,341	463,862	61	299	241,150	2,073	3,467	215	272
7	1,379,000	38,651	5,281	603,838	460,227	57	299	259,252	2,499	4,257	242	254
8	1,441,000	38,827	5,309	647,130	505,214	59	299	273,790	2,804	5,125	399	242
9	1,427,000	39,090	5,392	636,440	526,437	56	299	269,703	3,004	5,898	340	240
10	1,477,000	39,324	5,432	636,500	504,180	57	299	286,538	3,468	6,516	287	227
11	1,382,000	39,557	5,465	607,922	502,547	44	299	268,108	3,844	7,193	221	200
12	1,439,000	39,774	5,503	596,045	478,611	44	305	286,361	4,226	7,811	250	195
2012 -1	1,476,000	40,092	5,497	658,080	520,155	51	305	295,495	373	617	227	185
2	1,462,000	40,457	5,521	672,222	492,018	55	305	298,540	776	1,101	275	144
3	1,550,000	40,877	5,568	658,395	517,343	59	320	318,990	1,145	1,803	296	153
4	1,419,000	41,177	5,611	679,380	463,383	60	320	298,132	1,426	2,350	282	141
5	1,506,000	41,516	5,647	666,148	499,547	61	320	320,025	1,895	2,993	246	129
6	1,474,000	41,832	5,652	667,690	510,030	57	330	314,699	2,226	3,603	252	126
7	1,517,000	42,125	5,774	650,006	496,459	59	330	326,155	2,642	4,319	220	138
8	1,506,000	42,403	5,786	693,766	498,269	56	330	324,844	2,966	4,822	159	122
9	1,405,000	42,936	5,850	649,639	501,622	57	336	302,637	3,301	5,390	209	123
10	1,486,000	43,115	6,788	664,470	479,403	44	336	320,382	3,578	6,023	206	149
11	1,437,000	43,821	6,711	635,121	536,747	44	336	308,237	3,920	6,610	182	133
12	1,445,000	43,154	6,634	625,678	476,264	51	349	308,219	3,950	6,705	172	142
2013 -1	1,456,000	43,566	6,556	635,502	542,622	55	349	309,254	333	734	143	168
2	1,370,000	43,979	6,479	645,082	481,244	60	349	288,248	632	1,297	127	138
3	1,560,000	44,391	6,402	651,855	445,448	59	336	335,868	1,047	1,957	113	126
4	1,476,000	44,804	6,325	656,308	532,547	78	336	317,635	1,410	2,514	83	140
5	1,503,000	45,216	6,247	659,638	511,352	59	336	322,844	1,769	3,180	98	155
6	1,438,000	45,628	6,170	671,468	470,272	60	341	309,601	2,085	3,979	99	158
7	1,579,000	46,041	6,228	681,621	432,628	74	341	347,064	2,472	4,772	91	157
8	1,567,000	46,453	6,220	704,271	523,934	76	341	345,524	2,791	5,605	72	115
9	1,488,000	46,996	6,290	712,143	484,037	67	343	329,741	3,145	6,273	89	101
10	1,571,000	47,099	6,278	699,264	520,485	73	343	347,191	3,490	6,967	80	102
11	1,505,000	47,537	6,372	687,478	481,972	81	343	337,271	3,768	7,617	101	88
12	1,572,000	47,647	6,347	682,953	476,754	85	340	355,901	4,126	8,265	94	85
2014 -1	1,629,000	47,989	6,407	754,272	521,260	80	340	372,064	355	733	96	80
2	1,577,000	47,987	6,405	752,693	513,148	59	340	361,922	586	1,428	108	82
3	1,732,000	48,704	6,453	757,987	508,991	78	345	394,030	913	2,044	145	79
4	1,664,000	49,277	6,492	807,882	528,638	59	345	378,227	1,231	2,531	164	76
5	1,743,000	49,943	7,274	792,258	508,737	60	345	401,413	1,642	3,016	170	91
6	1,691,000	50,733	7,307	792,779	530,089	74	339	390,621	2,122	3,665	146	79
7	1,811,000	51,661	6,619	808,251	568,069	76	339	410,554	2,499	4,356	136	70
8	1,778,000	52,166	6,766	782,267	522,393	67	339	410,896	2,765	5,010	141	68
9	1,740,000	53,434	6,585	774,851	528,261	73	340	409,596	3,147	5,681	116	65
10	1,739,000	54,709	6,573	782,548	570,440	81	340	409,013	3,466	6,213	112	66
11	1,669,000	55,120	6,821	779,888	501,638	85	340	393,550	3,704	6,712	114	72
12	1,710,000	55,423	6,853	779,095	473,752	80	350	404,244	3,962	7,310	177	92

OUTPUT
Y = CWP -Clear water Production (Volume m3/month)
INPUTs
X_1 = DC - Domestic Connections (Numbers/month)
X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
X_4 = NDCONS - Non Domestic Consumption (Volume m3/month)

X_5 = QOW- Quality of Water (Number of sample tested/month)
X_6 = O&M - O&M Staff (Numbers/month)
X_7 = NRW- Non Revenue Water volume (Volume m3/month
X8 = RM - Rectification of Meters (Numbers/month)
X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- HAMBANTOTA Monthly Input & Output Data											
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	1,256,535	60,600	4,029	767,396	176,524	85	391	312,626	623	212	960	549
2	1,356,615	60,847	4,034	836,724	182,225	87	391	337,526	1,032	267	822	451
3	1,390,547	61,076	4,283	849,923	191,551	108	390	347,081	1,451	201	828	461
4	1,523,625	61,296	4,225	938,606	199,370	120	390	381,820	1,789	176	897	530
5	1,523,625	61,492	4,069	845,455	197,293	99	390	403,151	2,306	215	952	523
6	1,375,767	61,842	4,093	831,808	201,599	92	391	360,589	2,737	165	968	519
7	1,386,308	62,535	4,111	844,537	195,078	96	391	360,995	3,307	195	945	468
8	1,540,809	62,860	4,124	941,540	221,501	104	391	397,991	3,869	196	912	428
9	1,515,035	63,131	4,143	945,973	210,471	114	390	387,546	4,513	200	822	423
10	1,428,138	63,848	4,154	878,625	210,240	89	390	362,604	5,090	177	759	375
11	1,386,132	63,939	4,167	860,251	206,017	74	390	349,167	5,645	143	586	341
12	1,252,892	64,183	4,204	778,681	186,208	86	400	313,599	4,800	174	698	447
2011- 1	1,306,794	65,253	4,223	798,443	205,237	89	400	300,563	206	194	938	1,507
2	1,357,376	65,445	4,248	837,580	212,887	84	400	312,196	401	171	1,128	1,557
3	1,376,392	65,757	4,270	864,680	198,337	78	412	316,570	600	135	1,374	1,576
4	1,487,647	66,159	4,282	925,333	212,923	83	412	342,159	911	162	1,597	1,746
5	1,542,563	66,823	4,299	958,346	200,266	84	412	385,641	1,473	149	1,581	819
6	1,573,588	67,517	4,317	987,705	202,046	97	416	377,661	1,855	138	1,683	801
7	1,628,192	68,135	4,343	1,015,681	218,832	99	416	390,766	2,191	283	1,848	800
8	1,585,527	68,791	4,363	994,329	218,568	89	416	380,526	2,394	200	2,028	863
9	1,623,097	69,365	4,402	1,013,705	216,645	93	426	389,543	2,480	217	1,128	1,557
10	1,693,152	69,826	4,405	1,061,885	226,137	86	426	406,356	2,581	194	2,636	834
11	1,494,085	70,315	4,426	936,468	203,890	94	426	358,580	2,710	142	2,920	931
12	1,437,671	70,482	4,441	868,196	219,001	93	429	345,041	2,836	158	3,120	1,039
2012 -1	1,560,296	71,035	4,469	894,451	209,295	93	429	379,308	1,016	172	2,712	985
2	1,646,477	71,350	4,499	933,904	197,329	85	429	412,442	1,689	263	2,573	1,036
3	1,736,557	71,786	4,521	962,508	196,653	83	429	450,810	2,265	253	2,451	1,093
4	1,769,191	72,143	4,608	1,032,057	193,078	84	429	470,428	2,577	101	2,452	1,159
5	1,814,803	72,602	4,567	1,048,456	189,969	97	429	493,626	3,183	161	2,501	1,157
6	1,700,156	72,968	4,600	1,074,877	225,284	99	435	460,912	3,797	187	2,466	1,014
7	1,725,877	73,480	4,614	1,014,739	210,118	89	435	474,961	4,574	239	2,324	1,086
8	1,958,446	73,850	4,633	1,113,785	217,351	93	435	553,653	4,848	303	2,251	1,103
9	1,775,534	73,611	4,658	1,047,417	217,508	86	438	508,513	5,433	873	2,401	1,077
10	1,814,812	74,686	4,644	1,014,995	224,943	94	438	531,740	6,191	222	2,354	1,079
11	1,759,129	74,429	4,673	925,535	290,778	93	438	524,924	7,232	124	1,911	958
12	1,806,627	74,979	4,703	943,165	236,008	93	463	553,370	7,962	103	1,195	882
2013 -1	1,738,058	75,756	4,732	969,963	185,588	98	463	538,277	953	1,270	458	627
2	1,659,315	76,534	4,761	993,355	187,273	101	463	510,737	1,643	1,162	511	509
3	1,884,153	77,311	4,790	1,007,345	194,399	110	464	585,218	2,356	2,472	351	513
4	1,965,527	78,088	4,820	1,011,262	347,234	112	464	610,689	2,716	3,809	348	577
5	1,887,884	78,865	4,849	1,009,221	477,250	83	464	569,197	3,236	5,147	451	577
6	1,780,156	79,643	4,878	1,016,084	256,262	102	458	543,660	2,770	6,594	389	172
7	1,958,444	80,420	4,919	1,028,018	288,274	104	458	604,376	3,801	8,038	267	132
8	2,156,000	81,197	4,938	1,157,550	287,327	108	458	667,498	4,439	9,412	185	545
9	1,993,490	81,809	4,955	1,157,098	290,176	89	475	614,394	5,389	10,631	85	508
10	2,019,719	82,093	4,993	1,105,272	273,524	95	475	622,679	5,995	11,956	71	480
11	1,909,751	82,288	5,008	1,038,685	277,237	115	475	589,158	6,645	13,155	80	473
12	1,815,386	82,800	5,005	994,931	250,214	104	476	555,327	7,225	11,914	79	473
2014 -1	1,979,466	83,061	5,021	1,064,130	290,976	77	476	602,747	649	1,214	55	451
2	1,974,536	83,274	5,036	1,111,551	304,850	110	476	599,864	1,240	2,383	68	439
3	2,063,571	83,586	5,052	1,153,049	399,775	112	486	607,103	1,863	3,621	76	436
4	2,062,345	84,111	5,058	1,230,129	311,220	83	486	596,636	2,458	4,811	85	440
5	2,121,479	84,646	5,052	1,208,957	297,461	102	486	626,685	2,999	6,202	117	463
6	2,101,124	84,895	5,058	1,233,926	302,641	104	482	617,520	3,599	7,459	143	444
7	2,176,890	85,251	4,712	1,214,937	335,865	108	482	632,604	4,342	8,716	505	1,376
8	2,391,269	85,627	4,591	1,282,534	327,413	89	482	694,903	5,012	10,210	853	1,806
9	2,103,676	86,046	4,606	1,259,442	314,164	84	480	607,331	5,766	11,649	772	832
10	2,093,841	86,420	4,639	1,206,146	296,327	115	480	598,420	6,437	13,233	775	830
11	1,882,361	86,814	4,663	1,086,779	284,863	104	480	532,332	7,054	14,523	726	786
12	1,885,460	87,109	4,681	1,051,020	289,712	77	504	529,814	7,593	15,867	776	838

OUTPUT
Y = CWP -Clear water Production (Volume m3/month)
INPUTs
X_1 = DC - Domestic Connections (Numbers/month)
X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
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X_5 = QOW- Quality of Water (Number of sample tested/month)
X_6 = O&M - O&M Staff (Numbers/month)
X_7 = NRW- Non Revenue Water volume (Volume m3/month)
X_8 = RM - Rectification of Meters (Numbers/month)
X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- JAFNA Monthly Input & Output Data											
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	145,520	4,771	1,023	77,056	42,400	24	104	26,063	68	187	115	876
2	136,758	4,952	1,024	87,341	29,212	22	104	22,415	289	260	152	712
3	141,535	4,950	298	74,558	39,092	21	104	24,769	277	260	234	297
4	165,015	4,640	608	70,598	28,332	22	107	39,307	114	210	209	299
5	165,637	4,954	1,023	83,450	38,849	22	107	40,299	256	135	218	310
6	171,867	4,969	1,008	80,436	36,091	21	107	44,324	380	140	190	640
7	170,207	8,717	1,033	135,491	-19,218	22	107	45,462	250	118	196	572
8	150,733	5,154	1,038	87,881	36,432	22	111	38,588	287	165	174	554
9	142,455	5,234	969	83,359	35,933	22	111	35,101	298	180	174	564
10	159,135	5,380	969	85,467	31,587	24	111	39,513	303	207	157	533
11	153,934	5,415	949	82,265	31,618	22	111	38,376	225	165	110	948
12	164,103	5,507	958	78,495	31,699	24	126	42,060	160	130	133	891
2011- 1	143,598	5,576	960	78,106	30,707	23	126	34,751	126	89	128	594
2	149,846	5,593	963	78,210	31,456	23	126	40,159	91	86	162	624
3	147,850	5,639	963	81,805	28,139	24	126	37,850	176	71	181	549
4	178,187	5,647	971	84,767	37,251	24	126	56,129	266	65	190	579
5	170,865	5,680	1,360	89,998	35,118	26	126	45,792	272	63	184	551
6	170,535	5,749	1,009	94,235	37,172	27	137	39,052	238	58	186	535
7	180,059	5,783	1,033	96,737	34,082	27	137	49,156	202	65	214	539
8	179,437	5,799	1,033	94,057	34,230	23	137	51,140	214	62	256	591
9	178,874	5,909	1,037	104,789	35,422	27	137	38,637	331	54	202	572
10	176,979	5,988	1,041	96,976	33,978	27	137	46,015	295	64	178	621
11	174,268	6,009	1,050	89,464	32,993	27	137	51,758	140	70	152	679
12	176,829	6,046	1,053	86,484	34,080	25	153	56,232	186	74	158	751
2012 -1	176,117	6,141	1,077	89,441	30,113	43	153	48,643	80	67	140	669
2	159,011	6,202	1,085	93,741	26,815	44	153	43,585	171	43	146	592
3	174,970	6,239	1,084	91,277	28,849	34	153	48,747	254	20	211	543
4	188,460	6,339	1,095	99,875	29,907	43	153	52,486	135	9	184	554
5	188,957	6,355	1,095	98,901	28,301	66	153	53,588	98	9	160	563
6	174,459	6,451	1,099	105,823	34,504	48	153	48,988	65	12	90	377
7	171,764	6,477	1,100	97,783	32,511	47	153	47,785	43	6	189	499
8	167,617	6,513	1,102	96,198	33,505	47	153	45,843	12	12	202	489
9	175,642	6,544	1,112	99,957	32,586	46	153	48,477	26	18	221	465
10	159,120	6,623	1,114	93,814	29,214	46	153	43,535	44	6	199	502
11	173,085	6,722	1,116	91,613	32,537	39	153	47,148	23	21	213	447
12	178,686	6,810	1,117	87,596	30,966	37	153	48,960	12	14	203	498
2013 -1	180,841	6,867	1,119	90,524	33,980	32	153	49,424	12	19	217	456
2	167,004	6,925	1,120	94,496	25,515	40	153	46,143	8	8	183	435
3	180,343	6,982	1,122	96,547	19,636	38	153	50,496	8	10	139	240
4	171,366	7,040	1,123	98,244	32,442	42	153	46,903	8	5	165	405
5	170,375	7,079	1,125	98,832	28,111	38	153	45,541	22	29	175	351
6	211,005	7,154	1,126	99,455	37,403	42	204	59,419	20	15	170	320
7	222,432	7,212	1,145	101,225	37,349	41	204	65,551	14	10	168	286
8	230,700	7,269	1,164	111,019	32,288	32	204	71,194	4	7	117	287
9	214,016	7,524	1,177	122,300	40,578	37	196	65,681	17	13	121	227
10	221,779	7,591	1,183	110,905	34,700	38	196	70,060	19	8	115	213
11	205,768	7,791	1,190	110,119	36,613	39	196	64,981	10		74	174
12	209,095	7,905	1,196	102,948	32,840	33	204	66,346	6	20	80	170
2014 -1	184,152	8,307	1,265	103,819	30,451	49	204	57,842	6	72	85	178
2	204,316	8,378	1,270	113,612	34,407	42	204	63,992		65	154	183
3	208,829	8,689	1,271	121,853	35,527	46	218	63,547	10	63	94	164
4	197,813	8,785	1,288	125,321	50,912	43	218	58,038	10	69	118	102
5	198,341	8,876	1,315	123,957	37,083	37	218	57,063	39	71	111	146
6	250,161	9,218	1,330	145,305	44,823	38	222	69,470		70	158	157
7	263,101	9,716	1,336	146,238	48,886	37	222	70,301	27	68	165	151
8	261,109	9,945	1,347	141,175	38,268	46	222	68,384	311	72	121	129
9	248,679	10,109	1,336	148,762	42,608	43	222	64,855	303	68	105	110
10	213,961	10,328	1,347	135,325	40,369	48	222	52,913	358	150	68	153
11	198,492	10,573	1,362	129,597	41,971	48	222	46,804	349	150	78	593
12	223,245	10,826	1,363	119,196	41,373	48	230	51,458	278	150	112	178

OUTPUT

Y = CWP -Clear water Production (Volume m3/month)

INPUTs

X_1 = DC - Domestic Connections (Numbers/month)
X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
X_4 = NCONS - Non Domestic Consumption (Volume m3/month)
X_5 = QOW- Quality of Water (Number of sample tested/month)
X_6 = O&M - O&M Staff (Numbers/month)
X_7 = NRW- Non Revenue Water volume (Volume m3/month)
X_8 = RM - Rectification of Meters (Numbers/month)
X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- KALUTARA Monthly Input & Output Data

Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	1,043,000	39,991	2,334	549,973	113,774	44	208	379,235	290	602	1,385	1,415
2	944,000	40,099	2,341	552,032	109,274	41	208	314,446	645	1,291	1,453	1,834
3	1,047,000	40,182	2,433	549,405	118,466	38	207	359,226	828	1,838	1,405	2,308
4	984,000	40,267	2,357	595,107	110,836	48	207	323,047	974	2,242	1,555	1,989
5	1,015,000	40,465	2,368	568,583	115,130	44	207	332,819	1,532	2,731	1,394	2,471
6	997,000	40,642	2,374	545,151	107,045	52	203	329,907	1,729	3,373	1,402	2,344
7	1,038,000	40,799	2,373	525,998	108,651	54	203	352,297	2,176	1,074	1,280	1,871
8	1,070,000	40,892	2,388	569,069	112,371	57	203	366,475	2,746	4,730	1,087	1,415
9	993,000	40,971	2,395	580,984	111,999	39	202	335,733	3,345	5,285	923	1,408
10	1,019,000	41,111	2,438	560,376	130,514	36	202	342,894	3,547	5,890	904	1,328
11	959,000	41,185	2,470	558,703	104,416	43	202	320,402	3,682	6,552	1,068	1,394
12	1,006,000	41,308	2,490	547,810	115,626	46	197	336,608	3,855	7,173	1,139	2,020
2011- 1	1,018,000	41,493	2,505	558,118	122,904	46	197	336,856	387	989	1,056	1,672
2	916,000	41,598	2,517	560,981	125,768	46	197	229,641	630	1,703	1,122	1,772
3	1,004,900	41,645	2,524	563,731	114,155	42	184	326,994	783	2,636	1,244	1,323
4	996,080	41,771	2,531	613,236	129,843	56	184	253,004	898	3,179	1,376	1,416
5	1,041,131	41,870	2,552	592,011	124,704	64	184	324,312	1,265	3,529	1,281	1,370
6	997,280	41,942	2,577	583,892	119,621	59	185	293,699	1,527	4,218	1,188	508
7	1,020,050	42,108	2,598	609,469	125,462	53	185	285,104	1,830	4,830	1,437	1,024
8	1,067,300	42,194	2,603	603,474	117,479	55	185	346,339	2,119	5,538	1,387	1,307
9	974,290	42,254	2,632	610,595	121,027	39	186	242,696	2,449	6,187	1,091	1,728
10	1,050,790	42,524	2,651	610,060	120,251	63	186	320,491	2,630	6,755	1,202	1,470
11	991,820	42,603	2,666	591,365	119,219	65	186	281,280	2,788	7,394	1,364	1,441
12	998,510	42,873	2,669	572,541	114,632	60	183	311,335	3,182	8,024	1,385	1,309
2012 -1	967,190	43,085	2,699	577,879	116,660	64	183	280,485	317	603	1,274	1,318
2	908,810	43,209	2,713	581,753	109,466	69	183	262,828	497	1,201	1,405	1,281
3	1,036,460	43,386	2,730	608,376	114,530	56	194	297,775	905	1,743	1,382	1,276
4	1,083,500	43,450	2,749	678,757	124,234	64	194	311,506	1,175	2,308	1,324	2,333
5	1,142,860	43,686	2,764	661,503	114,435	59	194	329,829	1,637	3,116	1,354	1,248
6	1,078,190	43,857	2,780	653,887	122,136	51	203	309,872	2,082	3,821	1,134	1,233
7	1,138,460	44,042	2,808	664,375	126,860	53	203	329,698	3,085	4,517	752	1,120
8	1,114,850	44,183	2,845	705,438	130,665	39	203	315,614	3,545	5,077	641	1,088
9	1,089,380	44,505	2,875	663,722	128,595	62	202	310,364	4,161	5,724	453	1,110
10	1,116,140	44,800	2,898	664,025	120,635	65	202	317,319	4,664	6,368	403	1,081
11	1,092,780	44,739	2,922	644,666	130,566	60	202	311,333	4,944	7,042	496	1,014
12	1,128,280	45,468	2,946	648,450	130,240	64	203	321,560	5,110	7,658	621	988
2013 -1	1,143,008	45,758	2,970	654,332	127,487	58	203	329,072	412	439	523	972
2	1,010,357	46,048	2,995	659,367	153,565	71	203	287,042	822	613	515	970
3	1,218,362	46,337	3,019	663,818	112,928	20	199	353,203	1,274	979	54	950
4	1,125,296	46,627	3,043	666,319	173,470	31	199	325,548	1,691	1,241	523	948
5	1,139,677	46,917	3,067	669,700	191,211	62	199	322,301	2,043	1,607	545	985
6	1,038,294	47,207	3,091	678,340	150,490	44	201	287,296	2,572	1,945	437	840
7	1,085,693	47,496	3,100	687,730	103,919	52	201	297,263	3,098	2,326	332	912
8	1,122,559	47,786	3,137	695,504	145,731	56	201	307,469	3,533	2,745	244	1,037
9	1,122,664	47,494	3,157	694,614	151,633	34	201	304,916	3,934	3,147	225	937
10	1,107,705	48,363	3,190	694,971	150,613	58	201	295,314	4,387	3,516	227	944
11	1,077,299	48,033	3,199	683,830	153,987	89	201	281,175	4,782	3,765	270	912
12	1,083,195	48,837	3,248	693,363	150,022	69	202	274,807	5,074	4,037	280	900
2014 -1	1,120,197	48,508	3,273	738,825	166,215	71	202	272,320	291	401	351	903
2	1,117,131	49,470	3,294	753,458	166,268	20	202	269,340	669	695	371	1,021
3	1,097,372	49,206	3,320	727,087	162,253	59	205	247,677	1,092	1,164	429	1,007
4	1,165,225	50,124	3,346	788,716	184,207	62	205	254,019	1,489	1,534	384	1,116
5	1,141,555	50,621	3,355	768,667	161,792	44	205	243,037	2,003	1,943	356	1,103
6	1,137,308	50,901	3,378	757,734	173,266	52	201	240,086	2,393	2,306	240	1,131
7	1,140,964	51,172	3,394	764,824	164,866	56	201	232,757	3,017	2,717	99	1,155
8	1,142,813	51,495	3,398	759,001	176,735	34	201	226,506	3,482	3,117	84	1,151
9	1,109,605	51,753	3,607	746,557	164,951	58	229	213,710	3,967	3,659	88	1,205
10	1,168,148	51,962	3,937	746,557	175,543	89	229	222,532	4,413	4,223	95	1,129
11	1,122,856	52,479	3,937	734,047	170,019	69	229	211,434	4,752	4,703	62	1,174
12	1,147,923	52,702	3,432	716,265	165,657	67	230	217,417	5,245	5,181	83	1,191

OUTPUT

Y = CWP -Clear water Production (Volume m3/month)

INPUTs

X_1 = DC - Domestic Connections (Numbers/month)
X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
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X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- KANDY Monthly Input & Output Data											
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	3,854,404	146,912	9,843	1,905,256	757,680	163	703	1,191,396	991	1,619	2,802	2,413
2	3,674,881	140,444	9,886	1,969,623	733,350	118	703	1,055,793	795	1,621	2,531	1,980
3	4,493,855	141,405	11,359	2,024,524	821,842	143	718	1,424,552	1,011	2,007	2,923	2,023
4	4,417,753	142,816	9,948	2,233,657	820,825	135	718	1,390,267	1,200	2,335	3,037	3,341
5	4,535,748	144,275	10,021	2,004,568	794,725	124	718	1,494,075	1,215	2,335	3,051	1,725
6	4,332,892	145,602	10,114	1,961,690	794,051	118	722	1,453,252	1,365	2,426	2,953	2,007
7	4,529,474	146,912	10,329	1,926,664	822,537	124	722	1,558,592	1,377	2,545	2,877	2,395
8	4,264,251	148,386	10,773	2,042,526	840,687	114	722	1,456,668	1,530	2,626	2,437	1,516
9	4,271,888	149,344	10,493	2,082,180	793,878	146	732	1,450,306	1,594	2,553	2,178	1,264
10	4,288,472	150,968	10,590	1,993,264	812,150	85	732	1,456,794	2,974	2,560	922	754
11	4,198,225	152,361	10,692	2,072,052	828,241	145	732	1,417,741	1,158	2,280	775	758
12	4,176,626	153,568	8,361	1,921,762	837,666	144	714	1,410,864	1,109	3,359	763	819
2011- 1	4,242,513	155,111	10,827	1,959,928	854,702	197	714	1,569,730	1,042	3,551	648	2,036
2	4,030,036	156,074	10,874	1,943,156	793,926	143	714	1,209,011	987	3,359	662	1,466
3	4,381,584	156,860	10,911	2,070,906	832,695	134	721	1,643,094	1,146	3,612	769	1,107
4	4,399,787	157,882	10,991	2,290,943	847,910	105	721	1,495,928	926	2,291	716	1,287
5	4,414,938	159,240	11,107	2,327,280	836,757	191	721	1,289,162	1,313	2,414	1,255	1,583
6	4,387,278	160,426	11,164	2,250,779	873,725	225	729	1,263,536	1,193	2,225	1,522	914
7	4,455,167	161,359	11,278	2,217,174	899,400	130	729	1,523,667	1,564	3,502	1,874	975
8	4,708,762	162,578	11,393	2,231,753	888,477	183	729	1,586,853	972	2,683	2,250	824
9	4,581,965	163,667	11,738	2,376,340	891,743	177	729	1,544,122	972	2,683	2,551	704
10	4,753,652	165,110	11,726	2,429,691	946,707	138	729	1,473,632	1,080	2,805	2,840	683
11	4,383,429	170,326	11,824	2,361,158	802,189	129	729	1,271,194	1,341	2,310	3,124	660
12	4,367,165	167,962	11,933	2,211,694	873,938	161	731	1,288,314	989	2,425	3,393	1,167
2012 -1	4,499,177	169,119	12,017	2,424,573	896,297	167	731	1,335,806	1,020	2,498	3,180	2,976
2	4,238,971	170,490	12,079	2,346,737	838,834	217	731	1,234,812	189	2,496	3,237	712
3	4,614,659	171,529	12,135	2,546,931	924,593	135	820	1,309,640	1,598	2,482	2,830	937
4	4,483,056	172,595	12,220	2,553,308	897,955	124	820	1,251,221	1,876	2,569	3,305	878
5	4,759,433	173,529	12,216	2,524,870	886,194	118	820	1,328,358	1,956	2,530	3,723	726
6	4,602,835	174,916	12,425	2,593,982	873,798	124	826	1,269,002	2,068	2,689	4,471	830
7	4,796,907	176,485	12,548	2,632,599	837,975	114	826	1,312,913	2,189	2,571	4,583	1,032
8	4,594,842	178,419	12,668	2,541,727	686,458	177	826	1,241,526	2,354	2,687	4,579	1,151
9	4,465,214	180,058	12,748	2,590,313	761,121	138	841	1,193,105	2,358	2,796	4,553	1,533
10	4,883,617	175,568	12,839	2,532,345	871,724	129	841	1,310,763	2,654	2,763	4,519	2,415
11	4,721,299	184,128	12,983	2,459,836	862,188	161	841	1,274,751	2,448	2,798	4,302	1,632
12	4,423,126	185,673	13,126	2,349,482	806,669	167	845	1,192,032	2,491	2,863	4,095	1,526
2013 -1	4,146,940	186,591	13,270	2,371,648	792,154	217	845	1,109,721	2,544	2,846	3,425	1,696
2	4,396,308	187,520	13,413	2,406,756	749,374	310	845	1,188,322	1,951	2,879	3,036	1,518
3	4,529,032	188,438	13,557	2,435,590	897,956	336	872	1,246,843	2,046	2,819	2,510	1,511
4	4,701,488	189,544	13,700	2,448,145	1,144,203	379	872	1,295,730	1,647	2,930	2,935	1,515
5	4,382,414	190,362	13,844	2,445,475	1,006,169	332	872	1,182,814	2,037	2,912	2,343	1,248
6	4,502,236	191,214	13,987	2,456,047	793,728	392	844	1,226,859	2,287	2,957	2,356	1,000
7	4,193,201	192,197	13,628	2,483,698	625,733	390	844	1,136,777	2,752	2,936	2,156	880
8	4,699,393	193,015	13,756	2,526,808	859,389	364	844	1,266,956	1,878	2,820	1,441	940
9	4,526,939	193,700	13,874	2,652,514	856,348	300	883	1,210,956	2,069	2,986	1,179	915
10	4,795,072	195,035	13,974	2,637,427	864,214	310	883	1,268,297	2,230	2,986	628	969
11	4,627,563	196,299	14,114	2,536,029	857,022	313	883	1,211,959	2,250	2,941	69	1,306
12	4,693,176	197,471	14,175	2,426,785	835,307	318	859	1,237,121	2,056	3,043	80	786
2014 -1	4,660,856	198,357	14,285	2,530,056	842,802	263	859	1,243,050	2,055	2,970	1	666
2	4,598,435	199,263	14,377	2,677,255	874,690	379	859	1,205,710	2,188	3,266	3	642
3	4,822,917	200,153	14,444	2,714,421	853,943	332	871	1,245,277	2,449	3,892	2	570
4	4,850,775	201,074	14,496	2,995,061	933,826	334	871	1,233,067	2,124	3,853	15	898
5	4,945,915	202,367	14,580	2,876,485	866,474	392	871	1,268,627	2,558	3,110	29	691
6	4,771,857	203,384	14,680	2,715,008	935,032	390	864	1,206,803	2,621	2,783	132	766
7	4,793,088	204,507	14,780	2,637,676	851,827	364	864	1,217,924	2,402	2,805	59	756
8	4,878,989	205,532	14,902	2,779,582	897,672	300	864	1,226,090	2,163	2,730	3	822
9	4,811,813	206,516	14,780	2,829,045	905,175	310	857	1,208,246	2,188	2,967	2	1,244
10	4,859,084	207,528	14,902	2,799,681	888,073	313	857	1,208,454	2,242	4,680	2	935
11	4,358,908	208,313	14,000	2,671,542	896,270	318	857	1,055,292	1,948	4,532	4	625
60	4,392,971	209,157	15,060	2,519,672	858,444	263	886	1,037,180	1,994	2,735	1	634

<u>OUTPUT</u>

Y = CWP -Clear water Production (Volume m3/month)

<u>INPUTs</u>

X_1 = DC - Domestic Connections (Numbers/month)
X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
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X_5 = QOW- Quality of Water (Number of sample tested/month)
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X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- KEGALLE Monthly Input & Output Data												
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	780,903	33,842	3,038	453,459	99,824	40	216	227,633	415	366	888	410
2	741,357	33,910	3,035	441,789	97,279	38	216	209,359	690	513	804	426
3	748,816	34,023	3,249	433,101	97,386	54	217	213,712	829	591	857	369
4	828,982	34,233	3,049	512,968	113,537	54	217	227,473	884	611	829	499
5	791,675	34,369	3,058	457,157	104,127	54	217	219,927	937	669	830	484
6	787,739	34,507	3,073	434,776	101,153	70	217	224,348	1,178	849	889	559
7	727,302	34,605	3,077	413,308	97,467	92	217	208,445	1,444	993	841	391
8	781,117	34,662	3,233	445,294	114,630	86	217	223,478	1,742	1,141	384	240
9	793,485	34,663	3,101	445,294	123,981	59	217	226,699	2,040	1,300	498	262
10	801,717	34,872	3,103	437,016	104,497	56	217	232,257	2,130	1,444	571	261
11	801,050	34,965	3,125	433,947	104,459	55	217	234,948	2,255	1,583	692	298
12	766,221	35,184	3,146	423,651	100,161	55	220	226,188	2,309	1,680	658	261
2011- 1	834,873	35,288	3,158	466,577	134,448	54	220	252,800	415	366	607	300
2	736,027	35,363	3,167	458,057	97,238	48	220	219,336	690	513	662	362
3	814,989	35,438	3,171	449,769	106,764	55	220	238,384	829	591	591	373
4	789,122	35,445	3,197	448,013	102,435	55	220	235,947	884	707	609	735
5	734,895	35,693	1,596	269,332	274,384	54	220	221,203	937	826	561	739
6	830,209	35,968	3,236	501,231	115,493	55	212	255,704	1,178	1,067	716	864
7	826,648	36,130	3,287	470,060	105,430	57	212	249,482	1,444	1,250	966	836
8	839,064	36,645	1,640	468,315	99,253	56	212	253,397	1,742	1,390	1,223	980
9	827,755	36,478	1,662	476,155	114,558	56	212	250,313	2,040	1,527	1,238	886
10	904,559	36,559	1,676	485,612	117,732	63	212	277,247	2,130	1,644	439	250
11	855,002	36,659	1,701	453,901	103,597	64	212	263,341	2,255	1,780	1,536	1,139
12	889,603	36,651	1,714	488,872	114,145	64	207	275,777	2,309	1,872	1,869	575
2012 -1	937,316	36,721	3,409	488,019	115,500	64	207	287,381	140	97	2,093	489
2	946,512	37,127	3,415	504,067	111,888	68	207	298,151	324	152	2,176	638
3	921,965	37,444	3,462	488,923	109,463	55	211	293,185	597	193	2,331	604
4	1,042,506	37,508	3,488	526,438	114,097	54	211	339,648	784	245	2,432	675
5	1,069,897	37,941	3,580	530,640	113,790	55	211	360,876	1,131	311	2,460	687
6	1,073,416	38,342	3,598	572,297	128,935	57	213	369,470	1,313	379	2,515	990
7	1,009,340	39,600	3,607	522,646	119,852	56	213	352,159	1,754	440	2,697	718
8	1,060,330	39,906	1,808	585,013	118,000	56	213	370,691	2,044	523	2,360	801
9	1,029,781	40,181	3,669	576,473	122,356	63	221	362,071	2,423	620	2,209	760
10	1,028,352	40,185	3,691	570,318	125,531	64	221	360,540	3,244	710	1,627	734
11	913,706	41,123	3,710	507,133	106,804	64	221	318,883	3,786	886	1,576	794
12	893,049	41,440	3,728	487,334	110,799	64	232	312,210	4,667	959	1,169	715
2013 -1	991,885	41,638	3,747	498,382	117,248	68	232	348,747	402	130	1,012	860
2	970,049	41,836	3,766	503,770	145,436	51	232	339,614	691	292	1,109	1,103
3	985,408	42,034	3,784	507,033	148,261	38	231	343,710	960	486	1,192	923
4	1,075,744	42,232	3,804	507,713	188,048	42	231	372,207	1,306	636	1,046	1,026
5	1,027,646	42,430	3,823	504,853	200,535	54	231	348,064	1,947	839	970	1,019
6	935,368	42,628	3,840	512,151	108,497	72	231	315,967	2,296	1,049	869	500
7	890,685	42,826	3,854	525,615	94,068	71	231	296,598	2,743	1,295	956	436
8	998,228	43,025	3,909	575,721	128,557	85	231	328,816	3,109	1,473	830	974
9	956,551	43,057	3,914	541,482	120,193	100	234	314,131	3,448	1,694	804	790
10	998,615	43,346	3,953	529,872	118,009	96	234	330,342	3,702	1,890	755	863
11	974,390	43,518	3,966	512,477	125,718	95	234	323,692	4,081	2,159	755	863
12	908,890	43,802	4,015	484,828	112,161	95	236	302,842	4,521	3,544	834	800
2014 -1	1,008,351	43,910	4,020	563,238	125,351	51	236	330,638	980	384	881	765
2	966,956	27,230	4,043	611,866	134,824	38	236	308,846	1,318	366	1,123	746
3	1,082,966	44,332	4,058	582,453	123,712	42	240	347,307	1,846	348	1,042	764
4	998,095	44,583	4,086	630,116	127,738	54	240	310,408	2,184	316	1,022	861
5	1,044,816	44,711	4,105	623,502	132,501	72	240	321,490	2,743	352	1,010	845
6	1,019,271	44,854	4,125	568,144	126,768	71	237	312,203	3,067	327	1,151	775
7	973,160	44,982	4,134	550,223	129,079	85	237	297,884	3,218	305	1,184	697
8	1,029,872	45,143	4,161	575,730	110,280	100	237	318,745	1,217	372	601	639
9	1,007,148	45,307	4,173	579,653	123,865	96	234	311,108	1,868	398	371	605
10	968,683	45,515	4,186	562,079	128,665	95	234	294,092	2,400	388	278	557
11	1,002,940	45,587	4,179	562,346	129,143	95	234	301,684	2,823	354	351	590
12	976,283	45,657	4,188	522,572	122,020	95	241	293,666	1,800	342	402	668

OUTPUT

Y = CWP -Clear water Production (Volume m3/month)

INPUTs

X_1 = DC - Domestic Connections (Numbers/month)

X_2 = NDC - Non Domestic Connections (Numbers/month)

X_3 = DCONS- Domestic Consumption (Volume m3/month)

X_4 = NCONS - Non Domestic Consumption (Volume m3/month)

X_5 = QOW- Quality of Water (Number of sample tested/month)

X_6 = O&M - O&M Staff (Numbers/month)

X_7 = NRW- Non Revenue Water volume (Volume m3/month)

X_8 = RM - Rectification of Meters (Numbers/month)

X_9 = CCR - Consumer Complaints Received (Numbers/month)

X_{10} = CDM - Connections due to Defective Meters (Numbers/month)

X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- KURUNEGALA Monthly Input & Output Data											
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	924,000	32,637	3,932	419,152	305,825	51	338	199,030	79	480	441	441
2	931,000	32,816	3,956	440,741	301,674	51	338	194,579	261	1,009	493	493
3	946,000	33,200	4,354	484,835	316,958	51	338	179,645	422	1,531	491	491
4	953,000	33,578	3,998	506,039	321,423	49	338	166,870	624	2,131	572	572
5	953,461	33,991	4,023	459,141	305,301	51	338	171,432	808	2,715	570	570
6	949,539	34,233	4,043	471,785	295,718	55	338	172,626	921	3,290	555	555
7	953,000	34,715	4,073	472,240	307,613	51	330	173,255	1,324	3,898	581	581
8	955,000	35,017	3,690	492,975	309,859	58	330	173,619	1,735	4,421	490	490
9	957,000	35,652	4,113	506,190	308,547	54	330	167,954	2,234	4,550	117	117
10	959,000	35,586	4,128	465,842	331,897	40	329	167,633	2,429	4,744	181	181
11	959,000	35,941	4,262	462,116	307,908	40	329	169,551	2,685	5,068	317	317
12	951,000	36,685	4,296	417,712	302,722	42	329	173,367	2,874	5,404	325	325
2011- 1	890,000	36,938	4,326	417,148	308,530	36	329	159,577	375	370	364	364
2	847,000	37,172	4,342	433,855	292,671	38	329	146,192	770	580	385	385
3	1,003,000	37,498	4,359	460,150	344,186	40	330	169,708	1,167	720	381	381
4	976,000	37,931	4,378	524,081	321,047	42	330	162,504	1,566	960	384	384
5	1,004,520	38,191	4,409	494,934	325,198	46	330	166,951	2,058	1,450	481	481
6	1,009,480	38,675	4,443	529,184	344,342	49	328	163,536	2,588	1,670	502	502
7	1,066,000	39,258	4,477	544,039	348,912	43	328	172,692	3,184	1,800	575	575
8	1,074,000	39,831	4,536	569,084	340,884	33	328	169,799	3,829	1,780	616	616
9	1,051,000	40,432	4,615	580,192	339,066	39	323	164,482	4,598	1,729	736	736
10	1,079,000	41,104	4,648	587,131	343,363	41	323	167,137	5,392	1,743	752	752
11	1,015,000	41,530	4,687	548,951	328,494	46	323	157,224	6,242	1,700	799	799
12	1,052,000	42,038	4,708	529,522	338,988	48	323	163,270	7,239	1,880	946	946
2012 -1	1,034,000	42,554	4,806	545,477	319,010	73	323	159,029	1,185	150	1,127	1,127
2	984,000	42,575	4,810	562,438	276,331	56	323	151,634	2,547	300	1,313	1,313
3	1,072,000	43,592	4,873	580,632	290,604	85	323	164,445	3,989	450	1,387	1,387
4	1,050,000	43,902	5,342	602,713	310,143	100	323	160,650	5,365	600	1,314	1,314
5	1,069,000	44,890	5,523	601,364	311,458	97	323	160,350	6,437	750	1,026	1,026
6	1,053,000	44,991	5,002	629,446	302,497	96	323	156,160	6,939	900	466	466
7	1,052,000	45,458	5,017	600,006	293,271	105	323	154,960	7,442	1,050	477	477
8	1,068,000	46,038	5,075	644,725	291,505	72	323	154,646	7,972	1,200	503	503
9	1,050,000	46,281	5,108	648,984	275,708	95	328	151,515	8,713	1,350	707	707
10	1,028,000	46,900	5,138	652,815	270,708	92	328	147,415	9,575	1,500	823	823
11	1,024,000	47,682	5,230	653,196	213,467	133	328	148,378	10,681	1,650	1,046	1,046
12	1,040,000	48,304	5,328	653,890	230,299	129	337	148,512	11,822	1,800	1,086	1,086
2013 -1	1,044,000	48,650	5,400	654,645	235,962	126	337	147,622	1,152	26	1,109	1,109
2	1,022,000	48,962	5,560	655,775	227,643	115	337	143,591	2,063	99	868	868
3	1,083,232	49,218	5,700	657,080	246,853	126	344	150,136	2,994	141	901	901
4	1,097,046	49,540	5,825	658,235	310,164	129	344	150,844	3,728	195	710	710
5	1,111,722	49,925	5,870	659,035	306,824	130	344	151,417	4,729	314	956	956
6	1,086,000	50,282	5,910	659,235	295,961	128	347	148,348	5,751	384	995	995
7	1,119,845	505,811	5,445	659,819	287,401	131	347	153,419	6,692	459	916	916
8	1,165,341	50,941	5,486	660,506	355,431	147	347	160,001	7,603	556	873	873
9	1,142,897	51,208	5,527	663,671	359,281	152	345	155,320	7,462	641	839	839
10	1,143,953	51,817	5,557	646,225	365,088	153	345	154,319	9,462	718	959	959
11	1,135,121	52,246	5,591	634,042	359,415	160	345	150,517	10,506	817	1,010	1,010
12	1,149,460	52,726	5,632	598,567	366,789	154	342	153,568	11,515	898	1,010	1,010
2014 -1	1,213,570	53,010	5,667	655,397	388,390	153	342	161,526	1,029	150	1,002	1,002
2	1,208,514	53,438	5,704	689,788	385,056	152	342	158,315	2,051	300	1,010	1,010
3	1,261,691	53,742	5,740	691,285	395,204	172	342	162,758	3,117	450	1,012	1,012
4	1,281,460	54,328	5,783	749,115	388,251	180	342	164,539	4,196	600	1,063	1,063
5	1,229,755	55,452	5,813	718,385	394,773	175	341	153,965	5,371	750	1,160	1,160
6	1,091,084	55,881	5,841	709,727	388,675	181	341	125,911	6,485	900	1,115	1,115
7	1,258,632	56,242	5,886	701,917	402,423	185	341	142,225	7,997	1,050	1,512	1,512
8	1,217,953	56,657	5,928	719,631	385,495	176	341	134,097	9,450	1,200	1,395	1,395
9	1,204,976	57,167	5,958	696,276	387,576	185	344	132,186	11,048	1,350	1,538	1,538
10	1,218,432	57,619	5,918	697,027	391,029	186	344	132,687	12,799	1,500	1,680	1,680
11	1,190,255	57,781	5,936	650,520	395,092	186	344	129,381	14,303	1,650	1,473	1,473
12	1,172,260	58,075	595	600,573	400,658	110	346	126,252	16,221	1,800	1,362	1,362

OUTPUT
Y = CWP -Clear water Production (Volume m3/month)
INPUTs
X_1 = DC - Domestic Connections (Numbers/month)
X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
X_4 = NCONS - Non Domestic Consumption (Volume m3/month)
X_5 = QOW- Quality of Water (Number of sample tested/month)
X_6 = O&M - O&M Staff (Numbers/month)
X_7 = NRW- Non Revenue Water volume (Volume m3/month)
X_8 = RM - Rectification of Meters (Numbers/month)
X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB–MATARA - Monthly Input & Output Data											
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	1,301,169	58,438	3,415	830,873	470,296	163	365	271,034	19	50	693	1,013
2	1,277,471	58,819	3,414	831,361	446,110	164	365	256,261	27	34	614	902
3	1,295,013	59,065	3,657	844,463	450,550	166	360	259,909	33	47	627	902
4	1,365,067	59,305	3,431	915,710	449,357	167	360	267,963	13	33	828	899
5	1,366,370	59,738	3,451	902,399	463,971	175	360	268,082	6	21	393	847
6	1,301,568	60,207	3,471	857,986	443,582	169	357	253,806	32	18	214	810
7	1,304,754	60,620	3,481	852,172	452,582	167	357	255,862	6	50	103	757
8	1,351,407	61,038	15,807	876,007	475,400	172	357	265,687	29	97	100	659
9	1,371,757	49,136	3,518	686,519	685,238	179	354	269,962	25	59	40	617
10	1,340,189	61,785	3,527	866,801	473,388	130	354	267,904	3	30	20	586
11	1,297,637	62,109	3,536	871,029	426,608	107	354	252,520	28	10	2	579
12	1,282,069	62,386	3,549	835,843	446,226	132	358	249,875	26	27	8	564
2011- 1	1,315,554	62,684	3,561	862,665	452,889	123	358	241,404	30	308	10	566
2	1,298,178	62,933	3,709	862,876	435,302	125	358	235,100	18	203	11	571
3	1,352,198	63,273	3,773	876,070	476,128	124	358	254,754	70	295	264	93
4	1,480,099	64,017	3,809	968,227	511,872	108	358	284,179	6	231	138	332
5	1,491,094	64,510	3,804	998,113	492,981	101	358	283,606	22	306	30	580
6	1,481,604	64,732	3,848	978,287	503,317	117	359	281,060	18	224	9	590
7	1,466,549	65,241	3,853	951,401	515,148	126	359	278,644	3	362	4	593
8	1,472,832	65,468	3,899	956,296	516,536	124	359	280,869	14	413	291	618
9	1,505,181	65,875	3,940	973,763	531,418	122	359	287,640	21	429	290	584
10	1,503,038	66,150	3,945	976,699	526,339	123	359	287,381	24	368	320	617
11	1,368,637	66,458	3,973	935,339	433,298	123	359	256,209	23	356	466	601
12	1,376,065	66,744	4,001	894,640	481,425	163	357	257,599	28	330	9	588
2012 -1	1,470,183	67,084	4,030	962,288	507,895	137	357	274,189	15	394	192	592
2	1,579,340	67,461	4,045	965,772	613,568	151	357	301,812	18	291	72	562
3	1,741,673	67,721	4,060	954,943	786,730	108	355	353,211	18	326	79	600
4	1,716,990	67,922	4,080	1,023,010	693,980	101	355	357,992	19	229	49	570
5	1,737,151	68,280	4,100	1,045,756	691,395	117	355	374,877	21	281	31	562
6	1,723,326	68,607	4,126	1,037,074	686,252	126	355	383,612	0	545	8	548
7	1,728,291	68,976	3,766	969,525	758,766	124	355	402,000	0	283	4	569
8	1,642,257	69,452	4,195	1,066,823	575,434	122	355	383,139	18	242	11	529
9	1,633,578	69,729	4,200	1,000,125	633,453	123	354	388,465	6	232	3	517
10	1,687,046	70,346	4,246	967,987	719,059	123	354	415,688	0	286	30	538
11	1,609,497	70,130	4,290	981,610	627,887	163	354	407,203	0	276	5	524
12	1,708,088	70,995	4,333	984,019	724,069	137	353	445,469	19	315	13	523
2013 -1	1,723,065	71,652	4,377	996,480	218,521	151	353	465,055	0	268	51	528
2	1,649,231	72,310	4,421	1,006,440	230,129	200	353	447,436	21	270	111	542
3	1,813,534	72,967	4,464	1,011,263	203,217	156	366	494,007	16	358	91	581
4	1,807,940	73,624	4,508	1,017,404	315,762	210	366	492,302	0	362	63	612
5	1,800,454	74,281	4,551	1,018,367	293,575	190	366	491,344	0	427	22	600
6	1,719,150	74,939	4,595	1,026,550	206,157	194	362	471,563	14	334	19	16
7	1,758,867	75,596	4,573	1,033,724	169,139	198	362	484,040	0	392	13	22
8	1,827,093	76,253	4,640	1,083,704	202,071	128	362	516,154	0	370	17	625
9	1,741,751	76,501	3,782	1,076,159	201,772	168	357	494,135	0	434	13	653
10	1,786,097	76,923	4,392	1,045,029	200,205	209	357	507,966	0	300	18	635
11	1,748,550	78,155	4,737	1,060,387	193,729	171	357	502,708	0	350	7	633
12	1,835,069	77,773	4,791	1,025,111	206,644	214	356	533,822	0	362	13	641
2014 -1	1,843,925	77,491	4,586	1,083,831	206,950	110	356	537,135	0	209	33	671
2	1,666,634	77,665	4,851	1,083,941	216,824	156	356	481,491	0	199	21	638
3	1,838,474	78,038	4,891	1,089,707	201,741	210	361	525,987	0	305	17	645
4	1,820,257	78,204	4,924	1,179,481	208,862	190	361	516,953	0	215	47	658
5	1,856,877	78,742	4,925	1,189,733	210,422	194	361	523,082	0	194	25	670
6	1,789,952	79,272	4,946	1,125,303	207,422	198	368	500,113	0	269	26	822
7	1,852,694	79,624	4,987	1,101,993	210,074	128	368	514,123	0	321	18	753
8	1,832,015	80,065	5,034	1,150,935	211,038	168	368	502,155	0	295	41	868
9	1,755,738	80,292	5,063	1,094,484	206,751	209	370	506,882	0	316	61	860
10	1,876,524	80,725	5,088	1,101,291	214,050	171	370	536,311	0	327	55	1,100
11	1,745,163	70,130	4,200	1,091,802	212,286	214	370	493,532	0	333	40	847
12	1,812,993	70,995	4,246	1,068,083	214,518	110	391	509,451	0	332	57	890

OUTPUT
Y = CWP -Clear water Production (Volume m3/month)
INPUTs
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X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
X_4 = NCONS - Non Domestic Consumption (Volume m3/month)

X_5 = QOW- Quality of Water (Number of sample tested/month)
X_6 = O&M - O&M Staff (Numbers/month)
X7 = NRW- Non Revenue Water volume (Volume m3/month)
X8 = RM - Rectification of Meters (Numbers/month)
X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- MONARAGALA Monthly Input & Output Data												
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	373,865	18,512	1,452	219,559	45,707	46	124	108,608	150	127	428	196
2	373,647	18,620	1,469	227,466	42,292	47	124	106,228	149	187	306	402
3	412,670	18,737	1,509	246,039	45,195	47	124	118,766	140	253	282	122
4	437,289	18,782	1,476	270,422	46,544	46	124	124,365	143	225	263	116
5	388,037	18,911	1,498	230,354	44,405	47	124	110,901	179	232	179	223
6	438,534	19,125	1,505	267,524	52,859	47	125	124,061	127	263	137	137
7	407,751	19,281	1,509	256,370	47,119	48	125	113,763	100	285	156	176
8	426,120	19,393	11,957	268,473	48,650	47	125	117,567	107	314	151	127
9	410,800	9,133	1,515	126,317	191,416	46	126	111,080	148	288	174	148
10	400,525	19,794	1,529	252,309	54,456	34	126	106,860	118	295	186	160
11	391,234	19,890	1,533	246,816	51,806	34	126	103,364	135	336	191	157
12	372,750	20,021	1,538	223,577	47,630	34	132	98,704	116	164	146	157
2011- 1	384,297	20,099	1,540	228,795	54,157	34	132	99,917	150	127	183	171
2	369,048	20,212	1,545	224,323	50,074	34	132	95,952	204	349	292	221
3	358,669	20,322	1,557	221,249	42,337	33	133	96,841	185	338	264	145
4	433,486	20,460	1,571	273,433	48,955	35	133	112,706	195	280	223	83
5	428,115	20,541	3,223	436,580	48,960	34	133	107,029	220	314	214	139
6	454,301	20,669	1,599	292,296	58,223	34	128	104,489	84	37	267	122
7	484,599	20,724	1,619	313,008	61,697	33	128	111,458	181	343	344	80
8	481,107	20,929	3,299	310,581	56,820	34	128	115,466	235	313	344	78
9	467,111	20,951	3,311	306,410	55,129	39	128	107,436	217	312	300	119
10	457,927	21,068	3,320	293,390	60,981	32	128	105,323	52	323	378	69
11	428,154	21,069	3,326	270,768	56,081	25	128	102,757	94	260	448	68
12	415,620	21,354	3,360	259,806	52,443	26	128	103,905	100	308	440	58
2012 -1	444,810	21,782	1,725	268,666	63,423	27	128	107,555	100	350	547	133
2	450,545	21,857	1,733	268,759	66,874	27	128	108,987	357	749	472	134
3	437,041	21,946	1,752	271,644	62,296	33	131	104,802	454	1,133	419	100
4	474,155	22,105	1,750	300,789	66,350	32	131	112,517	497	1,441	463	125
5	510,650	22,618	1,762	331,145	63,895	34	131	120,054	773	1,835	501	96
6	546,220	22,903	1,773	345,012	74,642	39	132	128,526	899	2,260	450	137
7	525,070	23,070	1,781	328,364	74,136	38	132	123,864	1,018	2,685	575	140
8	525,070	23,337	3,639	326,690	65,260	36	132	124,704	1,240	3,145	549	94
9	537,480	23,503	1,823	335,131	70,872	29	131	128,511	4,757	3,544	491	79
10	523,450	24,002	1,823	335,140	70,772	37	131	125,471	5,069	3,859	496	131
11	472,260	24,006	1,837	293,467	65,825	37	131	113,295	5,378	3,900	417	144
12	443,156	24,050	1,852	273,325	62,323	37	142	106,136	5,555	4,132	296	70
2013 -1	443,579	24,276	1,867	283,597	62,600	38	142	106,237	4,380	3,300	334	184
2	463,813	24,502	1,882	292,057	72,293	38	142	108,393	4,220	3,540	355	150
3	489,782	24,728	1,910	292,712	44,552	39	143	115,882	2,510	3,620	368	161
4	489,543	24,954	1,924	297,865	96,680	38	143	114,553	2,560	3,401	316	77
5	488,229	25,180	1,938	298,262	90,208	39	143	113,464	1,900	3,850	16	86
6	517,409	25,406	1,933	300,234	86,970	37	143	119,004	1,890	3,621	0	15
7	529,765	25,632	1,950	304,198	104,345	33	143	120,945	980	2,884	1	12
8	516,905	25,859	1,958	355,502	80,827	34	143	114,443	952	2,885	3	6
9	520,460	26,067	1,962	351,278	70,426	33	142	112,367	647	2,645	5	7
10	510,826	26,191	1,975	351,127	75,461	34	142	107,835	456	2,561	0	2
11	453,072	26,330	1,979	333,939	78,579	34	142	93,877	524	1,852	0	3
12	484,528	26,517	1,990	301,041	64,362	34	142	98,601	762	1,643	1	2
2014 -1	500,235	26,809	2,007	314,041	78,064	37	142	99,297	798	1,964	1	4
2	508,241	44,234	2,027	331,942	77,816	39	142	100,886	782	1,864	1	5
3	573,075	27,420	2,040	333,305	82,107	39	144	109,687	432	1,745	2	6
4	534,405	27,613	2,058	377,466	92,694	39	144	101,590	412	1,732	19	10
5	573,610	27,816	2,059	352,953	83,998	37	144	107,896	462	1,234	128	20
6	595,313	28,079	2,078	380,100	88,475	33	146	110,847	473	1,300	1	12
7	565,790	28,186	2,082	406,172	78,402	34	146	104,219	335	1,475	3	17
8	576,815	28,308	2,096	384,176	78,990	33	146	106,480	385	1,100	15	39
9	570,592	28,468	2,102	386,120	84,688	34	154	105,274	321	1,025	2	25
10	549,679	29,131	2,108	376,007	75,308	33	154	102,790	324	1,036	2	24
11	529,043	29,747	2,168	386,258	46,739	33	154	99,883	354	1,005	5	17
12	543,985	30,150	2,107	378,164	36,284	34	163	103,738	356	1,007	1	11

OUTPUT
Y = CWP -Clear water Production (Volume m3/month)
INPUTs
X_1 = DC - Domestic Connections (Numbers/month)
X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
X_4 = NCONS - Non Domestic Consumption (Volume m3/month)
X_5 = QOW- Quality of Water (Number of sample tested/month)

X_6 = O&M - O&M Staff (Numbers/month)
X7 = NRW- Non Revenue Water volume (Volume m3/month)

X8 = RM - Rectification of Meters (Numbers/month)
X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- PANADURA Monthly Input & Output Data												
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	640,666	25,562	2,087	375,035	75,409	12	141	190,214	64	292	89	572
2	653,678	25,825	2,101	385,533	76,416	15	141	192,900	167	520	81	536
3	737,814	26,055	2,402	416,240	89,862	18	141	222,820	207	788	76	549
4	735,175	26,334	2,131	436,607	91,142	19	141	218,126	272	1,005	77	567
5	732,315	26,613	2,147	424,621	81,024	65	141	219,255	347	1,251	94	629
6	703,810	26,901	2,161	416,870	92,468	100	141	207,976	424	1,742	70	546
7	742,350	27,199	2,179	400,172	89,260	72	141	224,412	515	2,029	59	503
8	749,277	27,500	2,189	422,297	90,505	37	141	227,855	598	2,301	21	461
9	701,401	27,722	2,209	427,387	89,649	43	141	210,070	659	2,565	26	500
10	694,050	28,006	2,229	401,317	88,353	48	141	207,521	718	2,824	28	420
11	695,615	28,246	2,248	411,770	92,347	41	141	206,528	788	3,082	17	479
12	684,081	28,493	2,268	390,202	85,578	44	143	203,514	852	3,348	17	413
2011- 1	719,160	28,723	2,299	422,944	92,740	81	143	201,365	87	350	23	479
2	718,141	29,043	2,327	423,215	92,899	87	143	193,898	130	593	22	365
3	795,955	29,328	2,335	434,829	97,329	111	143	254,706	194	892	16	401
4	813,010	29,724	2,364	476,400	106,391	82	143	219,513	232	1,246	22	466
5	885,676	30,026	2,383	470,262	97,561	110	143	309,987	254	1,617	23	421
6	793,164	30,255	2,420	471,038	114,471	113	139	198,291	307	1,957	24	430
7	867,094	30,539	2,441	481,946	119,281	100	139	260,128	363	2,285	43	437
8	839,742	30,767	2,469	483,656	119,816	115	139	235,128	417	2,600	38	433
9	783,070	31,173	2,520	485,747	111,914	94	139	187,937	473	2,937	32	330
10	839,746	31,412	2,542	504,544	119,244	95	139	218,334	534	3,281	34	263
11	858,871	31,682	2,561	485,690	116,259	89	139	257,661	621	3,610	35	270
12	836,632	31,935	2,750	469,858	114,113	78	139	250,990	681	3,919	39	246
2012 -1	879,019	32,231	2,596	495,354	117,476	87	139	257,289	67	315	36	200
2	842,071	37,247	2,610	612,835	45,620	87	139	241,927	136	633	38	231
3	883,723	32,788	2,644	533,555	135,074	84	139	247,442	199	945	43	247
4	938,841	33,138	2,654	580,113	130,004	94	139	259,496	248	1,257	46	248
5	949,678	33,592	2,666	559,047	109,953	57	139	257,458	341	1,625	56	329
6	867,636	33,929	2,706	530,191	120,464	67	159	234,262	412	2,008	47	308
7	875,228	34,127	2,695	512,245	116,096	90	159	234,561	499	2,368	49	300
8	940,159	34,465	2,742	562,614	129,581	120	159	250,552	571	2,730	30	321
9	774,164	33,890	2,729	527,021	125,575	101	156	201,825	653	3,081	47	277
10	911,307	35,512	2,752	533,379	122,702	101	156	239,309	722	3,451	42	252
11	800,469	35,097	2,776	523,420	118,397	80	156	203,879	772	3,818	36	217
12	842,739	36,207	2,800	541,601	113,489	79	162	209,336	837	4,180	36	207
2013 -1	862,411	36,743	2,823	550,037	88,274	91	162	211,118	81	400	46	192
2	933,780	37,279	2,847	552,151	134,879	82	162	232,138	135	770	37	222
3	943,257	37,815	2,870	563,333	104,255	81	163	238,550	235	1,164	27	185
4	1,046,431	38,351	2,893	562,669	179,162	70	163	269,351	312	1,569	17	160
5	989,048	38,886	2,917	574,309	119,900	83	163	254,977	411	1,950	17	96
6	998,449	39,422	2,940	576,663	140,463	88	170	260,196	507	2,338	12	80
7	1,024,948	39,958	2,883	594,017	32,001	86	170	277,556	597	2,699	13	75
8	1,013,006	40,494	2,992	609,089	118,348	82	170	275,943	703	3,039	2	49
9	905,888	36,979	2,940	566,945	122,183	98	167	251,565	808	3,360	3	49
10	1,003,825	41,286	3,044	641,608	131,648	104	167	274,345	935	3,706	0	56
11	1,090,677	37,565	2,987	558,020	126,214	154	167	313,788	1,079	4,070	1	49
12	1,028,153	41,880	3,098	655,790	129,720	71	167	296,005	1,180	4,449	1	52
2014 -1	1,035,311	38,007	3,034	592,906	137,780	70	167	300,654	121	345	0	43
2	1,040,366	42,692	3,132	715,702	140,222	66	167	294,111	246	728	1	50
3	1,166,687	38,651	3,153	616,784	145,726	171	176	336,006	427	1,095	2	53
4	1,236,424	43,808	3,190	738,507	135,666	81	176	356,337	595	1,462	0	70
5	1,226,554	44,576	3,228	783,634	131,965	69	176	348,587	834	1,856	6	55
6	1,096,439	45,246	3,244	705,866	153,116	79	175	305,468	1,119	2,243	10	72
7	1,118,823	46,028	3,256	683,998	137,603	88	175	300,628	1,319	2,689	9	57
8	1,081,797	46,422	3,286	691,073	138,654	90	175	286,352	1,554	3,072	3	51
9	1,029,822	46,808	3,300	675,501	128,594	111	189	270,740	1,784	3,467	8	59
10	1,030,666	47,279	3,314	673,942	128,878	99	189	270,241	1,992	3,873	10	52
11	1,148,614	47,599	3,110	655,381	142,499	88	189	294,964	2,231	4,281	12	57
12	1,053,202	48,041	3,338	634,277	131,115	110	192	273,517	2,420	4,668	9	49

OUTPUT
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X_6 = O&M - O&M Staff (Numbers/month)

X7 = NRW- Non Revenue Water volume (Volume m3/month)
X8 = RM - Rectification of Meters (Numbers/month)
X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- RATNAPURA Monthly Input & Output Data												
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	669,332	25,757	3,717	368,827	101,677	76	217	198,859	114	48	593	631
2	623,494	25,868	3,757	366,188	94,591	76	217	174,391	216	75	720	610
3	614,502	26,003	3,854	379,811	85,084	70	215	164,687	226	71	756	637
4	704,512	26,076	3,801	429,243	108,036	67	215	182,962	332	132	709	585
5	648,598	26,195	3,807	376,811	95,107	73	215	170,127	369	52	719	475
6	642,150	26,305	3,825	363,296	97,026	73	210	170,619	456	180	412	473
7	636,432	26,419	3,847	350,078	97,258	73	210	171,900	380	126	444	421
8	644,536	26,570	4,507	386,442	100,318	71	210	172,091	270	72	496	417
9	736,825	26,020	3,877	381,975	101,194	71	211	203,806	226	150	397	408
10	654,542	26,792	3,897	384,543	105,361	59	211	179,410	407	89	345	372
11	638,815	26,917	3,921	363,803	102,803	69	211	174,844	290	215	195	306
12	694,687	27,034	3,933	365,118	109,515	59	218	192,776	324	199	283	395
2011- 1	662,204	27,133	3,948	372,165	105,055	54	218	165,551	263	162	366	414
2	612,499	27,217	3,967	373,607	106,192	50	218	140,875	423	362	479	462
3	635,734	27,298	4,047	380,393	108,194	50	218	146,219	619	526	456	427
4	659,090	27,897	3,998	405,656	91,200	54	218	151,591	919	707	522	473
5	656,607	27,675	3,361	407,339	58,505	50	218	157,586	1,143	823	475	380
6	659,090	27,797	4,020	394,876	106,945	61	206	158,182	1,356	912	492	381
7	682,563	27,956	4,048	412,051	106,112	64	206	156,989	1,569	992	572	407
8	682,563	28,064	3,422	405,126	106,609	74	206	156,989	1,782	1,074	492	326
9	778,369	28,305	3,432	447,452	131,625	63	208	179,025	1,995	1,364	561	265
10	753,643	28,619	3,439	438,546	118,680	75	208	173,338	2,208	1,558	766	519
11	717,772	28,951	3,458	411,990	119,752	72	208	172,265	2,236	1,707	989	463
12	725,958	29,027	3,454	408,208	115,898	72	208	174,230	2,449	2,036	921	411
2012 -1	715,864	29,141	4,342	395,868	115,038	84	208	182,760	2,460	309	751	402
2	733,095	29,268	4,362	413,461	115,567	87	208	190,678	2,236	388	878	484
3	718,015	29,398	4,391	409,696	115,389	54	219	188,838	2,210	306	948	545
4	794,428	29,487	4,405	449,005	122,357	50	219	211,238	2,258	290	908	610
5	750,042	29,713	4,415	427,079	110,564	61	219	199,211	2,156	501	939	595
6	730,480	29,818	4,424	406,248	117,098	64	218	196,572	2,145	285	720	619
7	729,897	29,914	4,436	409,204	113,445	74	218	198,897	2,045	461	648	650
8	759,231	30,123	3,558	451,467	114,869	63	218	206,966	2,012	471	640	640
9	770,372	30,239	4,456	451,905	119,627	75	226	210,157	2,006	468	746	591
10	763,615	30,330	4,464	451,906	110,424	72	226	208,543	2,089	344	651	620
11	750,305	30,736	4,477	452,460	110,430	72	226	206,484	2,045	361	651	620
12	753,275	30,933	4,491	401,353	118,891	74	239	209,260	2,036	337	537	685
2013 -1	710,441	31,091	4,504	407,374	125,278	76	239	195,300	2,130	393	432	593
2	683,069	31,250	4,517	414,271	115,047	79	239	184,975	2,160	396	463	551
3	715,744	31,409	4,530	420,508	113,622	79	241	192,965	1,980	386	519	566
4	780,340	31,568	4,544	424,508	150,365	98	241	209,209	1,960	378	572	633
5	784,418	31,726	4,557	425,243	169,131	93	241	207,479	1,890	306	652	553
6	748,609	31,885	4,570	429,659	106,451	100	236	198,082	1,840	341	734	447
7	744,045	32,044	4,584	433,952	117,301	99	236	195,386	1,760	316	565	406
8	767,860	32,203	4,616	449,521	129,672	105	236	201,026	1,720	302	510	376
9	788,685	32,323	4,651	462,549	131,471	103	234	205,768	1,680	348	532	240
10	795,862	32,535	4,672	464,170	135,767	103	234	206,367	1,590	321	504	304
11	792,156	32,675	4,701	452,504	139,083	103	234	203,346	1,580	362	503	273
12	782,239	32,940	4,719	430,390	127,655	103	227	199,393	1,420	386	534	279
2014 -1	798,147	32,971	4,742	460,568	136,197	103	227	203,527	1,400	384	547	287
2	789,269	37,266	4,763	464,008	136,811	79	227	201,974	1,230	366	457	292
3	760,478	33,248	4,727	446,596	133,230	98	234	193,542	1,182	348	465	303
4	803,113	33,557	4,751	483,342	107,951	234	25	204,392	316	311	312	4,004
5	852,067	33,682	4,758	486,807	146,600	100	234	217,959	1,080	352	591	209
6	878,194	33,919	4,778	477,628	142,685	99	232	225,784	1,040	327	573	209
7	826,320	34,113	4,823	478,753	142,470	105	232	211,703	1,064	305	622	215
8	838,561	34,399	4,860	504,393	134,508	103	232	214,168	1,023	372	447	233
9	868,990	34,875	4,887	501,935	140,627	103	232	222,983	1,074	398	369	180
10	866,956	35,189	4,908	498,202	145,247	103	232	223,241	1,069	388	393	188
11	843,301	35,372	4,897	474,810	150,678	103	232	217,487	920	354	427	209
12	812,668	35,516	4,887	459,005	144,834	103	239	207,718	1,021	342	484	218

OUTPUT

Y = CWP -Clear water Production (Volume m3/month)

INPUTs

X_1 = DC - Domestic Connections (Numbers/month)
X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
X_4 = NCONS - Non Domestic Consumption (Volume m3/month)
X_5 = QOW- Quality of Water (Number of sample tested/month)
X_6 = O&M - O&M Staff (Numbers/month)

X7 = NRW- Non Revenue Water volume (Volume m3/month)

X_8 = RM - Rectification of Meters (Numbers/month)
X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- TEC south Monthly Input & Output Data												
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	2,075,056	80,723	5,406	1,392,153	339,430	90	268	343,422	271	315	1,011	1,453
2	2,079,938	81,269	5,431	1,385,148	346,435	78	268	346,310	575	665	986	1,316
3	2,084,330	81,606	5,969	1,429,635	304,948	82	268	347,875	1,111	1,148	1,087	1,203
4	2,082,536	82,094	5,523	1,477,936	265,647	77	268	345,493	1,691	1,313	645	1,204
5	2,085,256	82,705	5,561	1,445,138	306,612	88	268	343,442	2,226	1,607	258	1,101
6	2,082,758	83,139	5,593	1,436,090	331,076	129	271	338,448	2,637	2,376	168	920
7	2,084,844	83,491	5,632	1,390,703	388,214	127	271	333,992	3,223	2,959	81	868
8	2,087,958	83,879	999	1,408,872	378,212	132	271	330,315	3,554	3,539	20	639
9	2,097,771	90,857	5,726	1,530,308	269,525	152	271	328,091	3,855	3,952	20	479
10	2,097,453	84,689	5,762	1,371,466	433,701	107	271	324,476	4,164	4,482	2	401
11	2,095,281	85,044	5,803	1,436,626	380,041	130	271	319,949	4,549	4,965	1	291
12	2,090,925	85,412	5,833	1,329,969	492,364	144	276	315,102	4,905	5,438	1,011	1,453
2011- 1	2,092,703	85,824	5,871	1,444,927	379,157	108	276	268,703	312	556	0	313
2	2,091,887	86,261	5,915	1,399,732	430,185	97	276	261,904	673	1,072	6	261
3	2,084,745	86,632	5,960	1,458,867	373,134	111	281	252,671	1,186	1,735	0	204
4	2,089,726	87,030	6,008	1,586,707	257,960	53	281	245,125	1,476	2,303	0	242
5	2,098,208	87,472	6,048	1,498,785	348,048	61	281	251,365	1,879	2,904	3	198
6	2,120,301	87,826	6,102	1,465,700	385,884	77	282	268,642	2,336	3,416	1	248
7	2,132,855	88,291	6,145	1,551,818	311,933	91	282	269,166	2,667	4,065	0	191
8	2,151,102	88,845	6,195	1,559,840	322,911	112	282	268,458	2,939	4,686	1	185
9	2,163,157	89,511	6,315	1,554,236	340,181	81	292	268,664	3,322	5,330	0	233
10	2,183,249	90,189	6,378	1,600,054	313,862	146	292	269,413	3,595	6,009	0	183
11	2,199,456	90,927	6,435	1,542,100	386,150	124	292	271,193	3,900	6,702	1	189
12	2,216,536	91,424	6,488	1,532,535	417,048	98	293	266,871	4,250	7,358	0	167
2012 -1	2,236,537	91,855	6,561	1,597,054	372,863	121	293	274,199	373	924	1	225
2	2,255,375	92,430	6,624	1,669,918	323,915	127	293	274,930	640	1,598	1	163
3	2,277,236	92,957	6,674	1,621,480	400,681	112	296	275,546	985	2,091	57	30
4	2,310,846	93,491	6,719	1,738,601	291,977	108	296	280,537	1,302	2,571	1	219
5	2,334,684	93,971	6,761	1,851,961	204,366	111	296	283,197	1,582	3,131	41	244
6	2,359,600	94,496	6,804	1,647,455	447,706	128	277	283,388	1,934	3,689	246	209
7	2,380,567	94,847	6,845	1,529,177	575,921	108	277	283,764	2,218	4,340	430	194
8	2,380,617	95,368	6,895	1,648,323	449,588	118	277	282,579	2,816	5,024	284	367
9	2,383,717	95,950	6,944	1,608,871	494,540	103	288	281,755	3,555	5,656	5	201
10	2,385,104	96,452	6,986	1,608,900	495,512	98	288	280,727	4,059	6,251	24	194
11	2,393,841	96,872	7,030	1,660,114	446,380	102	288	281,276	4,332	6,972	54	242
12	2,402,048	97,263	7,075	1,601,971	513,857	90	289	282,000	4,821	7,564	125	194
2013 -1	2,408,942	97,685	7,119	1,613,132	496,447	97	289	283,773	460	537	94	194
2	2,412,478	98,107	7,164	1,627,438	481,140	102	289	286,361	789	1,054	197	218
3	2,395,362	98,529	7,208	1,633,787	456,891	98	296	287,204	1,204	1,639	300	254
4	2,387,675	98,952	7,252	1,643,822	443,880	87	296	287,237	1,701	2,200	382	192
5	2,383,801	99,374	7,297	1,649,210	442,683	90	296	287,486	2,244	2,750	296	207
6	2,380,451	99,796	7,341	1,673,466	403,784	103	297	289,939	2,810	3,300	376	197
7	2,369,315	100,218	7,390	1,690,218	381,615	105	297	290,478	3,340	4,081	209	268
8	2,384,782	100,640	7,452	1,691,255	380,411	110	297	294,998	3,913	4,722	175	212
9	2,406,181	101,013	7,486	1,727,584	345,250	99	290	301,735	4,410	5,233	180	198
10	2,420,240	101,392	7,527	1,678,233	403,683	108	290	308,097	4,982	5,857	89	257
11	2,444,350	101,811	7,560	1,714,061	375,356	110	290	316,299	5,438	6,399	108	195
12	2,461,202	102,276	7,614	1,686,929	406,571	103	299	324,879	5,793	6,870	108	195
2014 -1	2,479,526	102,656	7,662	1,843,255	257,495	97	299	333,248	410	542	258	205
2	2,498,497	102,992	7,724	1,807,482	314,767	103	299	341,045	824	1,021	319	198
3	2,525,855	103,408	7,780	1,809,217	332,605	120	300	350,084	1,347	1,547	483	219
4	2,558,193	104,072	7,826	1,858,382	299,083	118	300	361,217	2,054	2,121	636	252
5	2,574,656	104,690	7,780	1,825,587	334,770	115	300	372,038	2,549	2,779	215	431
6	2,593,520	105,340	7,826	1,826,959	340,874	127	301	382,804	2,991	3,331	453	252
7	2,593,520	105,839	7,866	1,804,049	397,618	114	301	387,991	3,788	3,929	249	93
8	2,631,140	106,466	7,933	1,918,240	309,427	109	301	398,355	4,175	4,584	179	262
9	2,630,799	107,121	8,001	1,804,724	448,360	118	299	399,092	4,673	5,382	245	271
10	2,634,962	107,773	8,076	1,790,990	473,510	120	299	399,724	5,201	6,004	313	296
11	2,632,259	108,342	8,189	1,715,683	560,567	114	299	396,945	5,780	6,585	276	288
12	2,635,117	108,860	8,215	1,702,814	574,769	128	327	394,214	6,174	7,379	363	265

OUTPUT

Y = CWP -Clear water Production (Volume m3/month)

INPUTs

X_1 = DC - Domestic Connections (Numbers/month)

X_2 = NDC - Non Domestic Connections (Numbers/month)

X_3 = DCONS- Domestic Consumption (Volume m3/month)

X_4 = NCONS - Non Domestic Consumption (Volume m3/month)

X_5 = QOW- Quality of Water (Number of sample tested/month)

X_6 = O&M - O&M Staff (Numbers/month)

X7 = NRW- Non Revenue Water volume (Volume m3/month)

X8 = RM - Rectification of Meters (Numbers/month)

X_9 = CCR - Consumer Complaints Received (Numbers/month)

X_{10} = CDM - Connections due to Defective Meters (Numbers/month)

X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- TNC Monthly Input & Output Data												
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	3,139,162	89,099	5,314	1,586,952	839,214	41	282	712,904	1,110	1,524	3,416	5,144
2	3,192,693	89,421	5,333	1,563,648	868,436	39	282	742,940	1,981	2,139	3,082	4,173
3	3,261,906	89,604	5,685	1,543,304	887,113	40	282	783,836	2,582	5,697	3,122	3,163
4	3,308,474	89,935	5,387	1,665,198	782,968	42	282	811,569	3,147	7,018	2,405	4,482
5	3,361,102	90,260	5,438	1,657,988	797,012	33	282	841,284	3,521	8,402	2,200	3,037
6	3,416,937	90,885	5,465	1,594,069	880,681	45	289	870,636	4,276	10,974	2,394	2,364
7	3,448,643	91,368	5,510	1,567,331	925,086	48	289	890,095	4,968	13,956	2,513	1,697
8	3,499,347	91,799	6,307	1,669,068	835,515	42	289	915,429	6,032	16,434	2,234	1,302
9	3,540,372	91,601	5,586	1,630,907	895,343	61	289	936,428	7,283	19,082	1,639	1,266
10	3,580,838	92,894	5,611	1,549,422	999,412	78	289	956,084	8,362	21,465	1,468	1,181
11	3,628,966	93,167	5,694	1,539,229	1,017,687	77	289	979,095	9,281	23,930	1,161	1,351
12	3,678,694	93,946	5,745	1,535,629	1,037,204	69	289	1,002,444	10,081	25,672	1,276	1,074
2011- 1	3,685,767	94,408	5,768	1,031,939	1,544,767	70	289	1,105,730	642	794	760	928
2	3,681,144	94,647	5,808	1,622,602	957,019	74	289	1,098,085	917	1,637	1,280	1,033
3	3,646,127	95,082	5,824	1,643,381	944,574	94	288	1,045,709	1,206	2,411	1,596	1,027
4	3,636,429	95,243	5,849	1,768,361	824,345	57	288	1,030,928	1,503	3,097	1,678	1,123
5	3,616,672	95,724	5,924	1,838,122	769,500	78	288	971,076	2,277	4,603	1,663	1,898
6	3,599,664	96,488	5,979	1,745,469	878,044	75	293	820,003	3,051	6,109	1,525	1,248
7	3,590,754	97,165	6,022	1,757,072	888,274	79	293	883,685	3,821	7,174	1,718	1,106
8	3,573,163	98,081	6,074	1,682,383	965,964	93	293	875,068	4,381	8,119	93	1,239
9	3,561,417	98,897	6,141	1,702,280	961,380	49	298	766,773	4,867	9,077	2,140	1,494
10	3,549,854	99,732	6,209	1,703,018	971,849	62	298	856,225	5,830	10,081	2,270	1,490
11	3,551,803	100,217	6,286	1,699,225	994,059	62	298	854,919	6,324	11,331	2,201	1,503
12	3,548,800	101,237	6,364	1,647,786	1,058,372	64	293	857,035	7,717	12,259	2,049	1,664
2012 -1	3,551,711	103,026	6,418	1,807,566	915,594	56	293	936,231	2,134	2,580	1,827	1,531
2	3,562,921	105,522	6,501	1,884,154	880,668	74	293	916,383	2,251	2,518	1,611	1,798
3	3,600,310	106,706	6,546	1,853,386	966,273	39	291	903,678	2,118	2,400	1,841	1,755
4	3,663,575	108,084	6,663	2,091,505	749,370	29	291	900,140	2,212	2,418	1,862	1,527
5	3,734,483	108,895	6,717	2,065,606	812,336	52	291	901,878	2,084	2,200	2,227	1,335
6	3,811,238	110,422	6,844	2,002,580	913,849	55	315	908,980	2,030	2,558	2,069	1,321
7	3,870,447	111,644	6,967	1,948,643	989,386	63	315	915,748	1,775	2,600	1,851	1,567
8	3,951,899	114,105	7,033	2,106,649	857,676	75	315	932,648	1,685	2,784	1,314	1,523
9	4,049,400	116,633	7,139	2,089,705	910,973	70	317	958,898	1,800	2,890	1,318	1,450
10	4,139,902	118,080	7,195	2,048,886	987,927	56	317	988,609	2,065	3,100	1,536	1,463
11	4,206,437	119,976	7,287	2,034,941	1,036,456	84	317	1,015,434	1,784	3,030	1,396	1,895
12	4,278,206	120,878	7,378	2,082,271	1,030,085	70	324	1,046,449	1,656	2,800	1,421	1,601
2013 -1	4,348,086	122,211	7,470	2,096,738	1,041,743	121	324	1,080,499	2,035	2,700	1,307	1,252
2	4,417,927	123,544	7,561	2,116,051	1,039,936	102	324	1,121,270	2,184	2,615	1,463	2,476
3	4,419,410	124,877	7,653	2,132,937	1,023,713	103	345	1,146,395	1,998	2,300	1,622	1,955
4	4,438,844	126,210	7,744	2,144,290	1,020,102	81	345	1,173,630	2,028	2,100	1,746	1,445
5	4,433,030	127,543	7,836	2,156,987	1,024,089	79	345	1,190,712	1,784	2,300	1,730	1,579
6	4,423,408	128,876	7,927	2,206,796	982,649	126	345	1,203,167	1,684	2,400	1,695	1,469
7	4,434,194	130,209	8,005	2,247,468	935,295	71	345	1,220,290	1,885	2,100	1,604	1,195
8	4,437,403	131,542	8,140	2,198,010	995,408	101	345	1,231,823	1,760	2,084	1,616	1,270
9	4,431,150	132,882	8,238	2,251,238	951,996	141	348	1,236,291	2,430	1,908	1,721	1,282
10	4,416,564	133,847	8,321	2,251,140	977,687	126	348	1,232,663	1,884	1,834	1,720	2,149
11	4,430,107	135,181	8,392	2,223,762	1,032,649	109	348	1,234,671	1,890	1,703	1,568	1,518
12	4,419,285	136,027	8,505	2,245,869	1,041,875	90	345	1,225,468	2,035	1,674	1,670	1,650
2014 -1	4,432,103	136,694	8,573	2,555,453	747,541	81	345	1,220,601	2,200	1,626	1,830	1,720
2	4,457,642	137,764	8,656	2,532,174	826,570	86	345	1,212,924	1,625	1,607	1,815	1,387
3	4,513,722	138,633	8,752	2,341,671	1,053,073	113	347	1,213,740	1,784	1,583	1,833	911
4	4,566,084	139,615	8,846	2,536,046	889,990	33	347	1,213,209	1,615	1,650	1,988	985
5	4,600,508	141,462	8,966	2,537,196	922,840	70	347	1,209,014	2,035	1,628	2,139	1,347
6	4,647,092	142,472	9,108	2,467,876	1,030,660	94	349	1,208,709	2,100	1,450	2,186	1,341
7	4,682,347	144,009	9,164	2,436,037	1,132,249	102	349	1,200,554	1,550	1,403	2,295	1,913
8	4,718,709	145,180	9,238	2,455,061	1,152,522	103	349	1,191,946	1,784	1,515	1,087	1,272
9	4,740,302	146,341	9,281	2,440,911	1,199,172	92	352	1,179,861	1,928	1,560	1,726	1,186
10	4,758,676	147,602	9,320	2,542,298	1,116,452	106	352	1,169,207	1,900	1,258	1,897	1,179
11	4,769,716	119,976	9,358	2,479,423	1,204,244	125	352	1,157,133	1,890	1,300	1,951	1,169
12	4,788,394	120,878	9,425	2,487,544	1,202,039	93	362	1,151,130	2,200	1,310	1,806	1,180

OUTPUT
Y = CWP -Clear water Production (Volume m3/month)
INPUTs
X_1 = DC - Domestic Connections (Numbers/month)
X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
X_4 = NCONS - Non Domestic Consumption (Volume m3/month)
X_5 = QOW- Quality of Water (Number of sample tested/month)

X_6 = O&M - O&M Staff (Numbers/month)
X7 = NRW- Non Revenue Water volume (Volume m3/month)
X8 = RM - Rectification of Meters (Numbers/month)
X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- TRINCOMALEE Monthly Input & Output Data												
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	804,253	27,832	1,259	357,130	139,853	50	150	307,305	214	203	819	1,450
2	756,870	27,889	1,260	371,366	129,274	53	150	273,230	399	285	808	1,175
3	833,760	27,934	1,308	395,536	100,480	51	165	313,744	277	260	818	1,129
4	820,890	27,974	1,280	436,400	143,121	57	165	291,662	259	233	832	1,007
5	830,477	28,003	1,282	418,947	166,827	59	165	284,771	364	197	784	957
6	818,659	28,191	4,346	460,860	126,669	63	182	272,368	527	228	638	1,630
7	844,698	25,127	1,291	380,306	145,651	62	182	286,606	462	192	590	1,386
8	824,495	28,304	1,297	419,759	151,698	52	182	276,371	372	204	479	736
9	781,370	28,327	1,296	430,203	130,501	66	161	257,540	385	236	458	1,507
10	824,496	28,348	1,299	410,851	186,926	59	161	267,137	303	207	455	1,334
11	749,595	28,340	1,310	409,209	122,030	50	161	240,845	316	203	431	1,674
12	818,948	28,353	1,324	383,075	148,036	54	154	265,175	221	202	338	2,743
2011- 1	814,400	28,362	1,316	364,152	131,908	56	154	317,616	126	89	332	1,989
2	757,190	28,451	1,328	356,692	155,893	55	154	242,301	91	86	465	1,732
3	710,354	28,539	1,331	363,566	116,657	51	154	227,313	176	71	580	1,692
4	843,960	28,818	1,343	438,300	205,497	51	154	202,550	266	65	598	779
5	808,061	29,140	1,357	430,517	138,845	52	154	242,418	272	63	637	1,672
6	912,459	29,637	1,367	464,409	191,036	59	152	255,489	238	58	761	1,664
7	942,908	30,135	1,376	453,863	181,299	56	152	311,160	202	65	818	1,637
8	828,456	30,464	1,388	457,815	124,520	47	152	248,537	214	62	794	729
9	886,664	31,016	1,399	475,571	203,324	45	152	203,933	331	54	916	1,649
10	838,041	31,111	1,407	439,927	160,377	52	152	234,651	295	64	930	1,647
11	794,656	31,713	1,421	440,519	146,444	57	152	206,611	140	70	927	1,736
12	783,124	32,255	1,433	387,889	163,572	51	152	227,106	186	74	914	1,672
2012 -1	702,560	32,567	1,437	369,072	122,748	37	152	201,986	206	65	974	1,507
2	757,725	32,902	1,444	391,196	141,779	54	152	216,330	233	65	983	1,584
3	791,476	33,061	1,447	427,210	127,575	51	151	224,621	247	63	1,034	442
4	872,950	33,209	1,453	464,624	150,169	52	151	252,108	280	63	1,014	483
5	897,947	33,388	1,462	462,506	172,166	59	151	259,237	286	63	1,077	425
6	939,989	33,601	1,929	486,009	180,704	56	160	272,127	908	62	729	1,122
7	905,218	33,797	1,476	467,899	167,709	47	160	259,617	685	62	542	1,018
8	894,164	33,545	1,491	462,717	170,016	45	160	256,089	218	61	754	1,001
9	799,084	34,137	1,466	438,656	181,229	52	162	232,613	253	60	880	69
10	842,700	34,312	1,500	447,240	149,943	57	162	245,816	311	59	1,041	1,040
11	712,986	34,506	1,504	458,639	52,102	51	162	209,333	303	58	1,156	98
12	697,800	34,635	1,509	465,602	36,165	37	182	204,107	358	58	1,373	1,066
2013 -1	691,664	34,764	1,513	471,902	28,387	40	182	201,205	349	72	1,321	1,153
2	727,650	34,892	1,518	490,424	33,427	42	182	210,727	278	65	1,471	1,004
3	734,600	35,021	1,522	489,548	30,466	47	173	212,299	308	63	1,482	25
4	859,705	35,149	1,526	492,877	126,054	53	173	247,251	241	69	1,803	985
5	905,780	35,278	1,530	498,818	147,151	61	173	260,050	510	71	1,821	991
6	860,292	35,406	1,535	502,688	106,471	62	181	246,990	490	70	1,872	982
7	892,442	35,535	1,541	506,058	123,192	48	181	255,952	414	68	1,932	1,023
8	938,626	35,663	1,566	506,909	154,946	48	181	269,479	375	72	2,017	1,051
9	961,216	35,888	1,568	512,831	169,730	38	179	276,253	715	68	2,034	95
10	948,445	36,753	1,574	525,310	157,520	51	179	271,635	804	150	617	127
11	945,307	36,879	1,580	527,297	151,981	58	179	270,452	707	150	468	297
12	817,596	37,106	1,583	455,605	133,613	58	182	233,751	456	150	412	318
2014 -1	864,437	37,327	1,585	459,537	155,247	61	182	247,921	349	72	389	1,127
2	830,050	37,410	1,610	451,509	142,852	47	182	238,224	278	65	344	1,115
3	795,782	37,575	1,631	446,348	118,575	53	182	228,310	308	63	310	1,080
4	989,158	37,840	1,654	551,646	162,244	61	182	283,493	241	69	297	1,097
5	1,124,844	38,195	1,661	539,016	169,857	62	182	331,941	510	71	329	1,099
6	1,021,655	38,757	1,662	578,265	145,636	48	185	301,490	490	70	430	1,135
7	1,020,189	39,030	1,664	567,716	163,798	48	185	299,936	414	68	836	1,192
8	1,038,550	39,293	1,674	593,782	152,456	38	185	304,087	1,375	72	1,819	1,704
9	1,003,058	39,424	1,678	548,573	166,656	51	189	293,394	1,715	68	2,147	1,603
10	949,075	39,683	1,674	526,939	145,965	58	189	278,459	1,591	150	2,285	1,630
11	876,450	39,817	1,681	484,250	137,605	58	189	257,852	1,707	150	2,420	1,762
12	849,899	40,127	1,697	465,938	136,221	61	211	250,720	1,458	150	2,438	1,746

OUTPUT
Y = CWP -Clear water Production (Volume m3/month)

INPUTs
X_1 = DC - Domestic Connections (Numbers/month)
X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
X_4 = NCONS - Non Domestic Consumption (Volume m3/month)
X_5 = QOW- Quality of Water (Number of sample tested/month)
X_6 = O&M - O&M Staff (Numbers/month)

X7 = NRW- Non Revenue Water volume (Volume m3/month)

X_8 = RM - Rectification of Meters (Numbers/month)
X_9 = CCR - Consumer Complaints Received (Numbers/month)
X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

NWSDB- TSC DEHIWALA Monthly Input & Output Data												
Months	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
2010 -1	2,746,667	81,492	5,039	1,524,026	472,003	68	256	750,664	587	1,395	2,086	5,246
2	2,792,900	81,714	5,043	1,471,229	515,913	69	256	784,805	1,467	3,323	1,749	5,142
3	2,827,565	81,852	5,123	1,471,270	503,936	58	256	814,056	1,729	4,489	1,695	4,793
4	2,865,106	81,957	5,029	1,610,484	369,445	61	256	840,336	1,939	5,552	1,708	4,939
5	2,902,304	82,117	5,048	1,540,431	441,732	57	256	865,177	2,285	6,538	1,761	3,864
6	2,945,947	82,311	5,050	1,489,886	495,941	61	256	892,327	3,113	8,451	1,836	3,426
7	3,001,466	82,637	5,071	1,466,060	521,094	52	256	925,052	3,941	10,364	1,569	3,163
8	3,045,480	82,814	19,974	1,529,921	454,814	60	256	954,453	4,499	13,357	1,343	2,863
9	3,091,945	68,098	5,098	1,252,953	732,363	65	256	985,403	5,060	15,726	1,331	2,725
10	3,118,640	83,145	5,112	1,489,913	495,234	49	256	1,008,568	5,741	17,470	984	2,617
11	3,145,938	83,339	5,138	1,522,097	461,965	62	256	1,031,553	6,572	18,906	872	2,590
12	3,178,333	83,554	5,144	1,455,716	526,760	58	256	1,055,842	6,990	20,459	958	2,583
2011- 1	3,193,587	83,758	5,152	1,526,109	446,086	52	256	907,617	353	1,791	994	2,517
2	3,178,077	83,927	5,116	1,481,108	494,974	68	256	888,273	695	3,502	1,051	2,422
3	3,191,070	84,022	5,128	1,623,851	368,249	56	256	1,104,110	1,054	5,150	996	3,149
4	3,189,546	84,242	5,120	1,784,769	226,940	55	256	1,041,068	1,256	6,303	1,144	2,760
5	3,180,574	84,455	5,141	1,625,870	390,353	60	256	997,110	1,378	7,548	1,431	2,619
6	3,164,616	84,906	5,169	1,531,182	486,457	52	235	1,020,589	1,639	9,300	1,689	2,496
7	3,139,166	85,170	5,207	1,468,011	548,878	55	235	984,756	2,265	11,382	1,371	2,506
8	3,127,987	85,531	5,230	1,518,325	496,312	63	235	975,306	3,275	13,858	868	2,552
9	3,120,095	85,859	5,271	1,603,098	417,786	68	242	919,804	4,047	16,218	646	2,324
10	3,127,668	85,980	5,306	1,655,209	378,483	70	242	854,792	4,529	17,966	698	2,270
11	3,131,625	85,980	5,342	1,506,611	526,804	56	242	679,876	5,422	20,785	1,216	4,417
12	3,145,103	86,088	5,417	1,402,281	625,638	61	244	682,802	5,952	22,577	865	4,351
2012 -1	3,171,270	86,481	5,481	1,814,050	249,291	70	244	1,142,609	745	2,417	864	2,696
2	3,162,728	86,520	5,559	1,741,984	344,611	78	244	1,129,410	1,344	4,737	750	2,487
3	3,144,022	87,063	5,590	1,609,990	493,102	83	246	1,111,097	1,809	7,025	815	2,211
4	3,135,464	87,406	5,717	1,678,066	402,026	65	246	1,099,294	2,124	8,759	884	2,072
5	3,146,380	87,762	5,816	1,701,050	391,846	78	246	1,094,940	2,643	11,088	1,059	2,113
6	3,154,291	87,946	5,838	1,686,544	421,083	58	259	1,089,492	3,315	13,671	931	1,934
7	3,151,565	88,129	5,900	1,642,603	488,651	64	259	1,079,726	4,162	16,632	500	1,896
8	3,156,844	88,333	5,933	1,756,338	386,517	71	259	1,072,380	4,676	18,980	464	1,884
9	3,144,861	88,469	5,955	1,660,759	498,237	66	246	1,058,246	5,169	21,195	396	1,733
10	3,136,485	88,589	5,983	1,680,003	483,104	78	246	1,045,077	5,890	24,069	156	1,620
11	3,135,054	88,778	6,012	1,629,532	540,184	72	246	1,033,627	6,428	26,694	171	1,645
12	3,115,935	88,894	6,040	1,595,581	594,277	68	249	1,012,367	6,815	28,966	360	1,593
2013 -1	3,121,354	89,045	6,069	1,604,238	562,259	70	249	1,002,579	623	2,749	237	1,493
2	3,154,491	89,196	6,098	1,613,967	541,336	71	249	1,007,229	1,102	5,469	221	1,629
3	3,147,807	89,347	6,126	1,618,541	520,854	67	246	1,002,262	1,566	8,573	340	1,522
4	3,158,539	89,499	6,155	1,622,409	519,596	72	246	1,001,889	1,972	11,106	361	1,424
5	3,130,729	89,650	6,183	1,621,552	517,725	72	246	988,058	2,470	13,048	319	1,304
6	3,128,117	89,801	6,212	1,639,455	497,181	78	249	983,480	3,032	15,180	167	1,028
7	3,120,979	89,952	6,275	1,655,430	468,352	84	249	979,987	3,697	17,418	72	973
8	3,136,191	90,103	6,315	1,664,840	452,362	78	249	985,705	4,247	19,384	45	1,154
9	3,168,149	90,238	6,377	1,682,071	421,594	68	252	1,001,769	4,757	21,221	111	1,105
10	3,168,380	90,453	6,405	1,650,559	452,687	77	252	1,008,812	5,321	23,986	172	1,043
11	3,192,889	90,611	6,441	1,649,481	458,932	84	252	1,025,237	5,744	26,406	273	1,023
12	3,197,197	90,751	6,469	1,615,558	492,875	69	256	1,038,130	6,700	2,800	280	1,090
2014 -1	3,185,892	90,919	6,532	1,764,775	346,680	80	256	1,042,742	496	2,194	288	1,127
2	3,189,789	91,060	6,557	1,639,971	492,171	85	256	1,047,846	926	4,467	360	1,144
3	3,157,003	91,236	6,573	1,618,869	507,266	88	268	1,038,654	1,356	6,740	252	1,036
4	3,150,098	91,406	6,613	1,678,375	448,843	72	268	1,037,327	1,850	9,201	253	964
5	3,120,697	91,593	6,655	1,766,547	357,092	77	268	1,028,270	2,344	11,584	358	1,177
6	3,152,646	91,860	6,673	1,790,275	346,194	79	269	1,040,058	2,801	14,277	345	1,183
7	3,152,646	92,049	6,738	1,614,081	521,027	82	269	1,041,004	3,486	17,640	144	643
8	3,137,016	92,241	6,771	1,690,822	462,116	78	269	1,033,019	4,064	20,457	194	1,050
9	3,105,933	92,401	6,738	1,659,095	497,916	78	264	1,015,019	4,620	23,055	135	1,009
10	3,113,937	92,868	6,771	1,683,304	475,131	68	264	1,009,850	5,131	25,685	148	939
11	3,102,920	93,061	6,806	1,653,638	542,884	77	264	994,176	5,642	28,618	155	935
12	3,101,330	92,213	7,837	1,603,139	600,719	81	262	980,330	6,070	31,422	200	923

OUTPUT
Y = CWP -Clear water Production (Volume m3/month)
INPUTs
X_1 = DC - Domestic Connections (Numbers/month)
X_2 = NDC - Non Domestic Connections (Numbers/month)
X_3 = DCONS- Domestic Consumption (Volume m3/month)
X_4 = NCONS - Non Domestic Consumption (Volume m3/month)
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X_{10} = CDM - Connections due to Defective Meters (Numbers/month)
X_{11} = DCDM- Defective Connections other than Defective Meters (Numbers/month

Annex 03 - Approvals for data collection from NWSDB.

Data collection technique: The approval from relevant department to collect data from NWSDB is attached here.

Project Director (GRWSP) through,
Deputy General Manager (Corporate Planning Division),
National Water Supply & Drainage Board,
Ratmalana.
31.03.2015

(4) Ms Prabodha
to arrange to provide data
4/2/15 DGM(CP)

Dear Sir,

Request to collect the details related to National Water Supply & Drainage Board performance data.

I am currently reading my final year studies of MSc in Project Management at University of Moratuwa, Sri Lanka. In fulfillment of MSc, I need to produce a Dissertation. To complete Dissertation, data collection is very important chapter before the analysis. To achieve this, quarterly observations (performances data for Q1, Q2, Q3 and Q4) have to be collected for each year for all districts covering 11 Regional Support Centers for the period from January 2007 to December 2013. The data sheets are attached here.

The topic of the research:

Stochastic Production Frontier Analysis of Water Supply Utility in Sri Lanka.

I would be most grateful if you could assist in my research by completing the attached data sheets by spending of your valuable time. Also, I assure herewith the information provided for this survey will remain confidential and will be used for academic purposes only.

Thanks & Regards,

Uditha Saman Vithana,

Mobile No: 077-5102014, 077-4440692

Email : usam_vithana@yahoo.com

(3) DGM (CP)
Agreed. Please assist.
2015/04/02

(2) AddGM (P&D)
For advice please
2/4/2015 DGM (CP)

(1) Mr Sumanaweera (DGM - Corporate Planning division)

Mr Vithana is working as a Civil Engineer in this Greater Ratnapura Project office & He is following MSC in Project management at University of Moratuwa. He needs some performances data of the NWSDB. So please make arrangements to provide requested data for his MSC thesis

Eng. G.G.N. Gunawardhana
Project Director
Greater Rathnapura Water Supply Project
National Water Supply & Drainage Board
No; 72 C, SriPada Mawatha,
Ratnapura

Project Director (GRWSP) through,
A.G.M (Billing) (Commercial Div.),
National Water Supply & Drainage Board,
Ratmalana.
08.05.2015

Dear Sir,

Request to collect the details related to National Water Supply & Drainage Board performance data.

I am currently reading my final year studies of MSc in Project Management at University of Moratuwa, Sri Lanka. In fulfillment of MSc, I need to produce a Dissertation. To complete Dissertation, data collection is very important chapter before the analysis. To achieve this, quarterly observations have to be collected for all districts covering 11 Regional Support Centers for the period from January 2010 to December 2014. The data sheets are attached here.

The topic of the research:

Stochastic Production Frontier Analysis of Water Supply Utility in Sri Lanka.

I would be most grateful if you could assist in my research by completing the attached data sheet spending of your valuable time. Also, I assure herewith the information provided for this survey will remain confidential and will be used for academic purposes only.

Thanks & Regards,

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Mobile No: 077-5102014, 077-4440692

Email : usam_vithana@yahoo.com