STUDY OF URBAN WATER DEMAND AND DISTRIBUTION SYSTEM RELIABILITY – A CASE STUDY OF MAHARAGAMA WATER SUPPLY SCHEME, SRI LANKA

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Degree of Master of Science in Water Resources Engineering and Management

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Sri Lanka

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Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science in Water Resources Engineering and Management

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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 expect where the acknowledgment is made in text.

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Dr. R. L. H. L. Rajapakse Date

ABSTRACT

The purpose of a water supply distribution system is to provide safe drinking water to each consumer with adequate quantity and acceptable quality. Due to ever increasing population density, the existing water distribution networks (WDN) cannot meet the increased demand and are facing issues of inadequate supply and low pressure. The WDNs are an important component of urban infrastructure since it is directly linked to health and happiness of urban population. For the operational as well as the design aspects, it is very important to estimate water demand, that is how much water is needed and the variation in demand, that is when it is needed.

Monthly consumption per connection derived for 13 years from 2002 to 2014 and the daily average flow obtained for Mondays through Sundays for five weeks in the Maharagama Water Supply Scheme, Sri Lanka were studied based on statistical analysis using Small Samples Theory. System water balance concept was used to generate the instant flow rate time series of demand from the available service reservoir level data and pumping data. System water balance calculation was performed for service reservoir in 10 minute time steps and out flow time series was generated. Generated out flow time series was analysed using Large Sample Theory of statistics. Level of service variation with the proposed parameters was assessed with Principle Component Analysis (PCA) and simple tabular methods. Results were verified with a field questionnaire survey conducted across the study area based on individual household connections.

Significant variation of flow could be identified during the day for Maharagama Water Supply Scheme (WSS). Diurnal problem curve derived from the field survey data indicates that there is a significant problem level, which is more than 40%, during the day. Water supply system’s pumping capacity was not adequate to cater the peak demand of the scheme. It reveals that elevation and the distance have a considerable effect on Level of Service for Maharagama WSS and the Service level has a significant effect on consumption quantity as well.

This study should continue to cover the comparatively old systems in Colombo and outstations. Such studies will be helpful and essential to understand the behaviour of the existing systems and to assess and evaluate the effectiveness of the new designs. This also helps to plan the augmentation work required in existing systems for service level improvement and to develop design guidelines for the future or forthcoming schemes of similar nature.

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NWSDB	-	National Water Supply & Drainage Board
WDN	-	Water Distribution Network
DPF	-	Daily Peak Factor
HPF	-	Hourly Peak Factor
ANN	-	Artificial Neural Network
PCA	-	Principal component analysis
PC	-	Principal component
LOS	-	Level of service
TEC	-	Towns East of Colombo
WSS	-	Water Supply Scheme
GND	-	Grama Niladari Divisions
DSD	-	Divisional Secretariat Divisions
NRW	-	Non-Revenue Water
GIS	-	Graphical User Interface
MNF	-	Minimum Night Flow
MSL	-	Mean Sea Level

1 INTRODUCTION

1.1 Background

The purpose of a water supply distribution system is to provide safe drinking water to each consumer with adequate quantity and acceptable quality (Steel & McGhee, 1979). As the population density increases, if adequate planning measures are not timely implemented, it will lead to numerous problems associated with inadequate supply and low pressure. Piped water is supplied to 43.4% of the population in Sri Lanka at present (NWSDB, 2013), which is approximately over 8.5 million people. However, disparities in service coverage across regions are still prominent, despite the massive investments made during the last few decades (over rupees 20,000 million a year) in the water sector in Sri Lanka. The total population in Sri Lanka was 20.30 million in the year 2012 (Census and Statistics Department, Sri Lanka, 2012). Out of this, 3.7 million dwell in the urban area, which amounts to 18.3%. At present, 80% of this population has access to safe drinking water where 43.7% is provided with pipe borne water supplies (NWSDB, 2013). Out of the piped schemes maintained by NWSDB, only 36% has the capacity to provide a 24-hour supply (NWSDB, 1999). Most of the other schemes have an average of 12-hour supply. Every year, more than 100,000 new consumers are added to the NWSDB database and the demand for pipe borne water is ever increasing. Hence, demand is a very important parameter which needs due consideration when considering service level maintenance or design of urban water supplies.

Water distribution networks (WDN) are important components of an urban infrastructure since it is directly linked to people's health and happiness. On the other hand, it demands high investments as well as excessively high operation and maintenance costs. Due to strong interconnection between the network components and hydraulic parameters, designing of a WDN becomes a complicated task. Traditional way to this approach is based on trial and error while using thumb rules and safety factors that usually leads to non–optimal solutions. Abunda et al (2014) quoting Banos et al (2010) concluded that even though several optimization approaches have been proposed in the literature, a completely efficient and accepted approach to optimize a WDN layout is not yet available and implemented in practice.

1.2 Demand in a Water Supply System

Water demand in an area is the result of water consumption by individual users and industries in that area, reflecting their behaviour and habits. For the operation aspect as well as the designing aspect, it is very important to estimate water demand, that is how much water is needed and the variation in demand, that is when it is needed (De Silva, 2011). The current practice in Sri Lanka is the using of basic statistical data such as population, growth rate and per capita consumption to estimate the water demand. In majority of the recently designed water supply projects in the country, assumed diurnal variations and peak factors based on results of foreign studies have been used without any reference to the local conditions.

Demand in an urban water distribution system comprises mainly four categories, namely, domestic demand, commercial demand, industrial demand and institutional demand. Generally, institutional demand is very less compared to the other three categories in Sri Lanka. Demand for domestic water is determined by various factors. Based on similar studies carried out in the past, the following factors can be considered as main parameters affecting water demand; Population serving or size of the area, Available pressure in the system, Climatic condition, Habits of people, Cost of water, Quality of water, System of supply and availability of alternative sources (Rajapakshe & Gunaratne, 2005; Jansen & Schulz, 2006; De Silva, 2011). According to a study carried out in Spain, the income, housing type, members per household, the presence of outdoor uses (garden and swimming pool), the kind of species planted in the garden and consumer behaviour towards conservation practices play a significant role in explaining variations in water consumption (Domene & Saurí, 2006)

1.2.1 Demand variation

The term demand generally used is based upon the average consumption of water. When it comes to planning and design, this average consumption is not sufficient. Significant variations can be observed in the water consumption in seasonal-, monthly-, and daily resolutions and also in hourly time scale. Further, demand variation can be observed even within different minutes of an hour.

Seasonal variations occur since higher use of water in hot climatic conditions and lesser use in cold or rainy seasons while household and industrial behaviours are reflected by daily variations. Most critical variation in terms of water distribution scheme is the hourly variation since catering that defines the main scope of a water supply scheme.

Sri Lanka, being a tropical country, the seasonal variations and monthly variations are not significant and usually ignored (De Silva, 2011).

1.2.2 Estimation of variations in demand

It is clear that the assessing of the variations in demand in the entire water supply system is of utmost importance. The accurate assessments will produce a near optimal design as well as proper operation, which leads to the improved service to the consumers.

Any underestimation of demand variations will result in an undersized water supply scheme, which will fail to deliver the required quantity of water at the correct pressure to the consumer. Although such schemes are capable of providing the required service levels at the beginning, they fail to do so toward the end of the design period. In other words, they reach the design year quite prematurely (De Silva, 2011; Abunada, Trifunović, Kennedy, & Babel, 2014).

1.2.3 Definition of peak factors

The peak factors are generally expressed as ratios of peak demand to their average demands derived through the demand calculation over a specified period (EH Johnson, 1999; De Silva, 2011).

In current water supply designs, two peak factors are generally used to simulate the variation in demand.

$$\text{Daily Peak Factor} = \frac{\text{Maximum Daily Demand}}{\text{Average Daily Demand}}$$

$$\text{Hourly Peak Factor} = \frac{\text{Maximum Hourly Demand}}{\text{Average Hourly Demand}}$$

The water supply systems are expected to meet the maximum hourly demand of the day with a maximum daily demand even at the end of the design period. The source of supply, pumping mains, treatment plants and the pumps are designed to meet the maximum daily demand, as the system has to supply the total quantity of water required on the day with a maximum demand while service reservoirs and the distribution system are designed to meet the maximum hourly demand.

1.3 Reliability of a Water Distribution Network

Reliability of a WDN has been defined in many ways in literature. As per Abunda et al (2014) some of the definitions mentioned frequently includes;

(a) "Ability of the network to provide an adequate supply to the consumers, under both regular and irregular operating conditions" by Xu and Goulter (1999)

(b) "Time-averaged value of the flow supplied to the flow required" by Tanyimboh et al (2001)

(c) "Probability that a system performs its mission under a specified set of constraints for a given period of time in a specified environment" by Lansey et al (2002)

Since water supply related services tend to be of primary importance, to guarantee good service levels in a sustainable way, the systems performance of the water supply scheme must be evaluated. The incorporation of performance assessment techniques in the management practices encourages efficient operation and continuous improvement.

1.4 Problem Statement

Managing water supply distribution networks (WDN) is becoming more and more problematic with the increasing population and the demand. The scarcity of available water, higher and more uneven water demand resulting from population growth in concentrated areas, increase in urbanisation, more intense use of water to improve general well-being, and the challenge to improve water governance are already posing a tremendous challenge in providing of satisfactory water services. Increasing demand for water has led to environmental problems such as overexploitation of water resources causing an imbalance of the ecosystem and it demands to use water in a sustainable way. Even though in modern context, the main concern is the supply side, whilst the demand is the main governing parameter that allows efficient management of water (Candelieri & Archetti, 2014a). Therefore, reliable estimation of demand is essential to operate a WDN effectively and efficiently while maintaining acceptable level of service to the consumers. Reliable forecasts have saved energy consumption and cost by 3.1% and 5.2% respectively in Netherland according to the recent studies (Bakker et al., 2013). It also helps to formulate strategies and implement policy decisions.

National Water Supply and Drainage Board (NWSDB) is a semi government organization responsible for production, distribution and maintenance of public water supplies in Sri Lanka as enacted by the act of 1974, amended subsequently in 1992. In recent project designs carried out in Sri Lanka, the factors such as hourly peak factor (HPF), daily peak factor (DPF) as well as the diurnal variation of the flow have been assumed and it is not explicitly explained with adequate justification. On the other hand, additional distribution schemes are being planned while the existing and operational networks have been reported to indicate under performance and inefficient service levels. Out of the piped schemes maintained by NWSDB, only 36% has the capacity to provide a continuous, uninterrupted 24 - hr supply (NWSDB, 1999). Most of the other schemes are reported to have an average of 12 ~ 18 hr daily supply.

Maharagama Water Supply Scheme is also reported to be facing problems in meeting consumer demands effectively. It is not explicit whether the lack of water availability in the system or the low level of distribution efficiency is the main cause behind this prolonged deficiency. Hence, it is vital to assess the demand and the reliability of the water distribution network in Maharagama water supply scheme as well as all other underperforming water supply schemes in Sri Lanka. When considering demand and reliability assessments, there is a lack of established guidelines for the assessment of water demand and evaluation of distribution efficiency for future development of plans as well as for upgrading existing inefficient systems.

1.5 Objective of the Study

1.5.1 Overall objective

The purpose of this study is to assess water demand and evaluate distribution performance of a semi urban water supply scheme, and propose management recommendations as an initial approach that will eventually lead to the development and establishing of guidelines for system assessment and operation.

1.5.2 Specific objectives

The scope of the present study is to carry out a water demand assessment and evaluation of distribution performance of the Maharagama Water Supply Scheme (WSS) and the specific objectives of the study are as follows.

The specific objectives of the study are:

1. To identify monthly demand variation of the Maharagama WSS
2. To identify diurnal variation of demand of the Maharagama WSS
3. To identify spatial and temporal variation of service level across the Maharagama water supply scheme
4. To evaluate implications of considered parameters on reliability of the system
5. To derive recommendations for developing guidelines for assessing performance of existing and design of future water distribution networks

1.6 Thesis Outline

This thesis is organized into eight (8) chapters as Introduction, Literature Review, Methodology, Data & Data Collection, Analysis and Results, Discussion, Conclusions and Recommendations. Chapter One includes general introduction to the study and study objectives. Chapter Two describes the state of the art techniques used by previous researchers by means of review of literature regarding similar and related studies. Methodology adopted in this present study is described in detail in Chapter Three. Chapter Four includes the description of data types, data periods used for the present study and data checking processes. Analysis and presentation of results described in Chapter Five with the derivation of predefined parameters. Interpretations and discussion of results are included in Chapter 6 while Chapter 7 and 8 describe conclusions of the study and further recommendations, respectively.

2 LITERATURE REVIEW

2.1 General

Studies on water demand patterns for urban water distribution systems have been carried out by a number of researchers in the recent past. The models of water use which are discussed in professional journals are based on the time-series data; e.g. (Chen & Boccelli, 2014; Kofinas, Mellios, Papageorgiou, & Laspidou, 2014a; Romano & Kapelan, 2014). Salas- LaCruz and Yevjevich first introduced the general time-series model in 1972 (Salas & Yevjevich, 1972) and they identified: trend (linear or quadratic function of time), seasonality (approximated by Fourier series), and stochastic part (modelled by a autoregressive stochastic model) as major components in water demand (Mizgalewicz, 1991). Time series analysis is a well-established statistical method for analyzing discrete, infinite series of random variables. A number of authors have applied the statistical methods of time series analysis in the field of water demand forecasting at different time scales (Candelieri & Archetti, 2014a; Chen & Boccelli, 2014; Kofinas et al., 2014a). When it comes to forecasting of future demand, auto regression models and multiple regression models as well as the artificial neural networks have been used (Jain, Kumar Varshney, & Chandra Joshi, 2001; G. P. Zhang, 2003; Ghiassi, Zimbra, & Saidane, 2008). Winters' Additive exponential Smoothing is the only model that is capable of producing a forecast based on few values and produce meaningful values for quarterly averaged data (Kofinas, Mellios, Papageorgiou, & Laspidou, 2014b). ARIMA, Winters' additive, ANN and Hybrid (ARIMA & ANN) models have been used with a reasonable success to forecast water demand by Kofinas et al in 2014. In addition, Small sample theory and large sample theory have been applied to analyse water use time series data and obtain demand variation for water supply schemes (De Silva, 2011).

The operational conditions of an urban water supply system has a great influence on the pressure stability and associated energy consumption as well as the associated water loss (Qiang, Qiuwen, Siliang, & Desuo, 2015; Sarbu, 2016). The efficiency of regulation was found to be affected by the scale and the water demand of the network. Through comparisons between the networks, it had been found that when the network had larger length and high water demand, the improvements enabled by Tank-Level Regulation were more obvious (Qiang et al., 2015). The ratio of water from the WSS is another factor influencing the regulation efficiency (Qiang et al., 2015). Qiang et al (2015) used an approach based on the hydraulic solver EPA-NET and genetic algorithm (GA) to optimize the operation of water distribution networks. Study carried out by Abunda et al (2014) incorporated demand-balancing tanks in network optimization and reliability assessment, running simulations for an extended period. They employed balancing tanks, both in optimization and reliability assessment processes successfully. Incorporating the demand-balancing tank at an appropriate location can increase the reliability of the network. On the contrary, the poor tank location can decrease the reliability (Abunada et al., 2014). If the tank elevation is too high, the pressure in pipes can be also high, which increases the probability of pipe failure and water losses. If the elevation is too low, the pressure delivered can be insufficient and leads to hydraulic failure (Vamvakeridou-Lyroudia, Savic, & Walters, 2007).

2.2 Water Demand Patterns

Literature indicated that in most of the cases above, Deterministic models are used to model time series by a series of seasonal, weekly and daily patterns considering physical nature. Stochastic models usually adopt a numerical approach since they are usually formulated by using statistical and probabilistic models that are built on historical data (Kofinas et al., 2014b). That neglects the statistical dependence of the parameters characterizing the consumption process (Fontanazza, Notaro, Puleo, & Freni, 2014). Statistical prediction models, machine learning and simple population based approaches were used for demand pattern prediction earlier (McKenna, Fusco, & Eck, 2014). Fontanazza et al in 2014 has proposed a statistical methodology for the definition of water consumption patterns based on return period and multivariate probabilistic approach. Candelieri & Archetti (2014b) used unsupervised clustering method for identifying urban water demand pattern again. The model described by Zhou, McMahon, Walton, & Lewis (2002) uses only two different patterns: one for weekdays and one for weekend days, including national holidays. Another model (Alvisi, Ansaloni, & Franchini, 2014) uses demand patterns for each individual day of the week. In all four papers, it was observed that the patterns change with the seasons. In Sri Lanka, according to De Silva (2011), no significant seasonal variation can be observed. Two-peak diurnal variation was identified for greater Colombo region by De Silva's study which is characterized by a morning peak around 7.00 hrs and evening peak at 19.00 hrs. The Hourly Peak Factor (HPF) for Pannipitiya area was observed to be 1.88 while maximum daily flow was observed on Sunday with a Daily Peak Factor (DPF) of 1.08 (De Silva, 2011). In Sri Lanka, the Final Design Report of "Towns East of Colombo Water Supply Project" (Nippon Jogesuido Sekki, 1997) has taken HPF as 1.6 and DPF as 1.12. In literature, it is indicated that there are four distinct periods of consumption can be identified during the day. A sharp morning peak around 8.00 am, moderate mid-day consumption up to 4.00 pm, relatively less peak at evening and low night consumption till 4.00 am (Butler & Memon, 2006).

2.3 Time Scale

Water demands can be considered and forecasted on various time scales. According to the House-Peters and Chang (2011), the considered time resolution for demand calculation can be categorized as follows:

- Long-term: 5 to 20 years (unit: 1-1,000 million m^3 per year);
- Medium-term: 1 year (unit: 1,000-1000,000 m^3 per day);
- Short-term: 1 day to 1 week (unit: 10-100,000 m^3 per hour);
- Ultra short-term: real-time to 1 h (unit: 0.1-1,000 m^3 per second).

The time scale for any water demand forecasting model is dictated by the purpose for which the model is to be used (Bakker et al., 2003). For the daily operation of treatment plants and pumping stations, a short-term forecasting model for the next 24 ~ 48 hours is needed. The output of the model can either be one-day forecast for general production flow control of water treatment plants, or hourly forecasts for detailed distribution pump scheduling and operation of clear water reservoirs.

Extensive research has been done to enable the forecast of the daily demand. To generate the daily demand forecasts, various techniques have been used. Univariate time series models which generate forecasts using observations as only input (Msiza

& Nelwamondo, 2011), Time series regression models which generate forecasts based on the relation between water demand and its determinants (Maidment & Miaou, 1986), Artificial Neural Network (ANN) models (Lertpalangsunti, Chan, Mason, & Tontiwachwuthikul, 1999; Jain et al., 2001; Babel & Shinde, 2011), Composite or hybrid models in which two or more forecasting techniques are combined (Zhou et al., 2000; Aly and Wanakule, 2004; Gato et al., 2007; Alvisi et al., 2007) are some of those techniques indicated in literature. In Ghiassi et al. (2008) and (Campisi-Pinto, Adamowski, & Oron, 2012), comparisons between several of the abovementioned techniques are presented.

A smaller number of researchers have studied the forecast of water demand on an hourly basis. The applied techniques to generate hourly forecasts are identical to those applied to generate daily forecasts: Time series models (Jowitt & Xu, 1992; Leonid Shvartser, Uri Shamir, & Mordechai Feldman, 1993; Chatree Homwongs, Tep Sastri, & Joseph W. Foster, 1994), Time series regression models (Zhou et al., 2002), ANN models (Ghiassi et al., 2008; García, Fernández, Luengo, & Herrera, 2010) and Composite models (Alvisi et al., 2007). Some forecasting models are used for pipe burst detection to generate forecasts with smaller time steps (e.g. (Eliades & Polycarpou, 2012; Guoliang Ye & Richard Andrew Fenner, 2014)). They observed that a one hour time step, that is used in most models, is too large to describe all the variations in water demand and the dynamics in the water demand in the morning peak around 8:00 hour are not described properly with a one-hour time step. The 15-minute time step describes the water demand dynamics in more detail, which makes a 15-minute time step more suitable for application in water distribution control. Application of the smaller time step in a less critical time domain will be less valuable, and application in an area with a highly variable demand might result in less stable forecasts.

3 METHODOLOGY

3.1 Methodology Outline

Historic water demand data was obtained from the National Water Supply and Drainage Board (NWSDB) based on metered data and Monthly Operating Reports. Daily inflow and daily pumping data were collected from the Maharagama Regional Support Centre. Hourly pumping data, 10-minute resolution telemetry data that indicates the real-time fluctuations of the water level of the service reservoir were also collected from Maharagama office.

Using the available data, the following parameters have been estimated in order to identify flow variation:

- Monthly average consumption per connection (which is the average monthly water consumption divided by number of connections)
- Maximum monthly consumption per connection (which is highest monthly consumption per connection during the year)
- Average day demand (which is the average daily water use for the year)
- Maximum day demand (which is the highest daily use for the year)
- Peak hour demand (which is the estimated use during the maximum hour of water use during the day)

These information were then tabulated for each set of monthly and weekly data. Although these parameters provided vital information on the system, they were not sufficient to draw definite conclusions on the overall system behaviours. Hence, further analysis by means of statistical analysis was needed to be performed on these data for elucidation of underlying trends.

3.2 Small Sample Theory for Monthly and Daily Variations

Monthly consumption per connection derived for 13 years from 2002 to 2014 and the daily average flow obtained for Mondays through Sundays for five weeks forms a relatively small sample. According to the Strawderman et al. (2012), the confidence limit for the population mean is;

$$\bar{X} \pm t_C \frac{S}{\sqrt{N-1}} \qquad (1)$$

Where X - Mean

t_c - Critical value of confidence coefficient which can be read from Table 3.1 where v = N-l or the number of degrees of freedom

S - standard deviation

N - size of sample (N < 30 or small samples)

The t_c is selected for 95% confidence limit for the current study.

3.3 Large Sample Theory for Hourly Resolution Data

Series of outflows calculated at particular time intervals at a service reservoir on each day forms a data series. This series of values pertaining to the particular time can be subjected to a statistical analysis in order to obtain a representative value subjected to defined confidence limit.

Thus, the confidence limits for the population means are given by;

$$\bar{X} \pm z_c \frac{S}{\sqrt{N}} \qquad (2)$$

Where $\bar{X}$ = Sample mean

Zc - Factor depending on that particular level of confidence

N - Size of population (N >= 30 or large samples)

S - Standard deviation of the population

Since, for this study the confidence level is taken as 95% and thus the confidence limit can be simplified as;

$$\bar{X} \pm 1.96 \frac{S}{\sqrt{N}} \qquad (3)$$

Three distinct values can be obtained for a series of values as arithmetic mean, upper bound and a lower bound by performing this statistical analysis (Strawderman, Lehmann, & Holmes, 2012). By performing this analysis on each instant of time, we can obtain a time series that provides the most probable day with their mean, upper and lower limits.

Then the flow envelope is drawn by considering the lower limit when the flow is less than the estimated average and by considering the upper limit when the flow is more than the estimated average. By this method, the overall mean value remains practically the same.

Table 3-1 Statistical Table for small samples

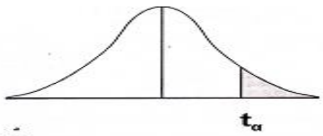

Table t Distribution

d.f.	$t_{.100}$	$t_{.050}$*	$t_{.025}$**	$t_{.010}$	$t_{.005}$	d.f.
1	3.078	6.314	12.706	31.821	63.657	1
2	1.886	2.920	4.303	6.965	9.925	2
3	1.638	2.353	3.182	4.541	5.841	3
4	1.533	2.132	2.776	3.747	4.604	4
5	1.476	2.015	2.571	3.365	4.032	5
6	1.440	1.943	2.447	3.143	3.707	6
7	1.415	1.895	2.365	2.998	3.499	7
8	1.397	1.860	2.306	2.896	3.355	8
9	1.383	1.833	2.262	2.821	3.250	9
10	1.372	1.812	2.228	2.764	3.169	10
11	1.363	1.796	2.201	2.718	3.106	11
12	1.356	1.782	2.179	2.681	3.055	12
13	1.350	1.771	2.160	2.650	3.012	13
14	1.345	1.761	2.145	2.624	2.977	14
15	1.341	1.753	2.131	2.602	2.947	15
16	1.337	1.746	2.120	2.583	2.921	16
17	1.333	1.740	2.110	2.567	2.898	17
18	1.330	1.734	2.101	2.552	2.878	18
19	1.328	1.729	2.093	2.539	2.861	19
20	1.325	1.725	2.086	2.528	2.845	20
21	1.323	1.721	2.080	2.518	2.831	21
22	1.321	1.717	2.074	2.508	2.819	22
23	1.319	1.714	2.069	2.500	2.807	23
24	1.318	1.711	2.064	2.492	2.797	24
25	1.316	1.708	2.060	2.485	2.787	25
26	1.315	1.706	2.056	2.479	2.779	26
27	1.314	1.703	2.052	2.473	2.771	27
28	1.313	1.701	2.048	2.467	2.763	28
29	1.311	1.699	2.045	2.462	2.756	29
inf.	1.282	1.645	1.960	2.326	2.576	inf.

There is only a 5% probability that a sample with 10 degrees of freedom will have a t value greater than 1.812.
* one tail 5% α risk ** two tail 5% α risk

3.4 System Water Balance

The system water balance is estimated based on the law of conservation of mass: i.e. any change in the water storage of a given control volume during a specified period must be equal to the difference between the amount of water added to the control volume and the amount of water withdrawn from it. A water balance model can be considered as a system of equations designed to represent some aspects of the hydrological cycle. Depending on the objectives of the study and the data availability, modelling can have different levels of complexity, although the model is a simplification of the real world, no matter how complex it may be. A simple tank or bucket model may be suitable for some purposes (L. Zhang, Walker, & Dawes, 2002).

In this present study, the control volume is considered as an intze type tank that is filled up by pumping and emptied by the demand supplied. When the tank is full, extra water is assumed to overflow to drainage. The only input data required by this model are pumping, and the available water storage capacity. There are a number of variations to the simple bucket model depending on conceptualisation of the system and methods for estimating. An example of such a model is shown in Walker and Zhang (2001).

$$\Delta\langle S\rangle = \langle P\rangle - \langle D\rangle \qquad (4)$$

Where $\Delta\langle S\rangle$ - the change in tank water storage

$\langle P\rangle$ - the pumping inflow

$\langle D\rangle$ - the water supply demand

System Water Balance Concept was used to generate the instant flow rate time series of demand from the available service reservoir level data and pumping data. System water balance calculation was performed for service reservoir in 10 - minute time steps and out flow time series was generated.

3.5 Principle Component Analysis (PCA)

Principal component analysis (PCA) is a type of regression analysis, which considers principal components (PC) as independent variables instead of adopting original variables (Pires, Martins, Sousa, Alvim-Ferraz, & Pereira, 2008). The PCs are the linear combination of the original variables, which can be obtained by principal component analysis (PCA). The PCA transforms the original set of inter correlated independent variables to a new set of uncorrelated variables (Haque & Rahman, 2013).

Level of service (LOS) under this present study was defined considering available pressure to the consumer and availability of water. Based on consumer complaints received and recorded, the study area was classified into three levels of LOS and sample areas were selected inclusive of all three categories of LOS and spatial representation. Then the sample sets of consumption data for each selected area were analysed and the spatial variation of monthly demand was obtained. Then the information of technical parameters under consideration in this study, such as elevation, connection density, Persons per connection, available pressure head, pipe diameter, distance from the service reservoir and level of service were tabulated for each sample area. The Principle Component Analysis (PCA) technique was used to analyse these tabular data.

3.6 Methodology Flow chart

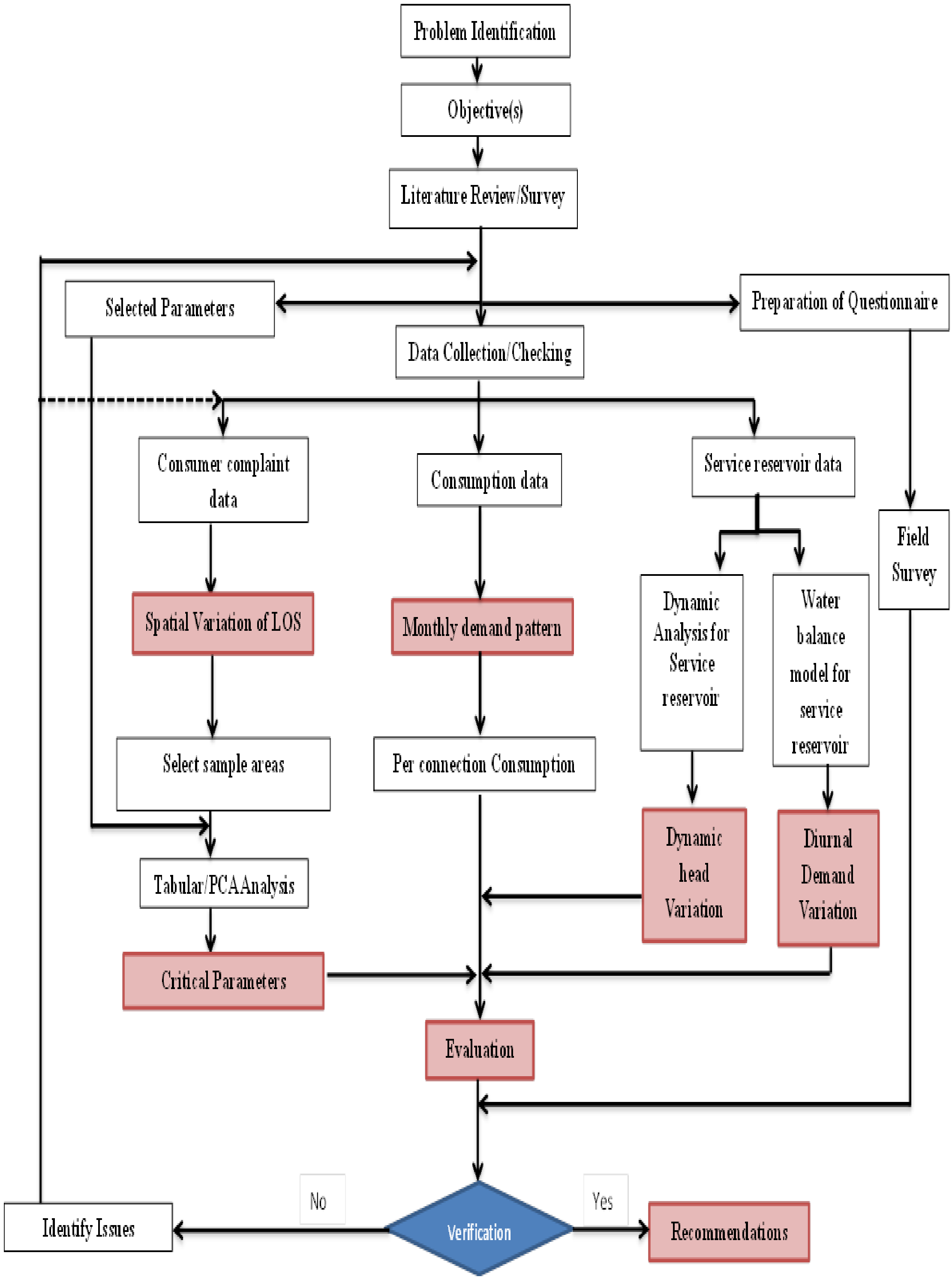

Figure 3-1 Methodology Flowchart of the Study

4 DATA COLLECTION

The Western Central Water Supply System is a very complex system with history of more than a century. It consists of a large number of ground sumps and elevated towers which serve as the means of service reservoirs.

The major service reservoirs (towers) in Western Central (Towns east of Colombo-TEC) Area are as follows:

Table 4-1 Major Reservoirs in Western central (TEC) Area

Name	Capacity (Cum)	TWL (m MSL)	BWL (m MSL)	Data Availability	Remarks
Kotte	1500	38.7	31.7	Partial	No Telemetry
Maharagama	954	45	38.5	Yes	
Pannipitiya	1000	52.3	48	Partial	No Telemetry
Kaduwela	2000	49.1	41	No	
Piliyandala	2230	50.1	42.1	Partial	No Telemetry
Kolonnawa	2000	36.4	29.3	No	

National Water Supply and Drainage Board (NWSDB) has installed flow meters in most of these service reservoirs. However, water levels are monitored by means of sensors and recorded in 10-minute intervals on to the computer system only at Maharagama reservoir.

On the other hand, Maharagama and Kaduwela can be taken as representative areas for most of the semi urban cities in Sri Lanka due to their inherent similar characteristics. However, the monthly meter reading values available (Billing data) were found to be inadequate to distinctly represent the weekly, daily and diurnal demand patterns in the service areas.

Therefore, it is clear that the selection will have to be made from the Service reservoirs with those outlets monitored by the telemetry system and considering representation of similar other cities.

The supplies into the most of these reservoirs are irregular and intermittent. As there is no sufficient water available at the reservoirs all the time, the distribution hours are curtailed. In certain cases, some ground reservoirs are used as pumping sumps to pump water to higher or distant places while distribution of water is continued to the low and nearby areas. In such cases, the reservoirs are emptied and the distribution of water is disturbed.

By considering these factors and situations, Maharagama water supply scheme was selected for the present study.

4.1 Study Area

4.1.1 Maharagama Water Supply Scheme

Maharagama Water Supply Scheme (WSS) supplies water to 29 Grama Niladari Divisions (GND) in Maharagama and Kesbewa Divisional Secretariat Divisions (DSD) in Sri Lanka with 28,950 individual connections (Figs. 4-1 and 4-2). From that, 26,726 are domestic connections while 2,220 are commercial connections. Population density in this area is 5,141/km^2 and household occupancy is 3.8 persons (Census & Statistics Department, 2012 Census). Average daily water consumption is 22,711 m^3 with 15-20% network leakage or non-revenue water (NRW) whereas it is going up to 33.43% in western province (NWSDB Annual Report, 2013). Average household monthly consumption was 16.9 m^3 in 2013 (NWSDB Annual Report, 2013). Average per capita consumption is approximately 148 l/h/d. Domestic connections are growing at a rate and demand for water is increasing with the growth of population as well.

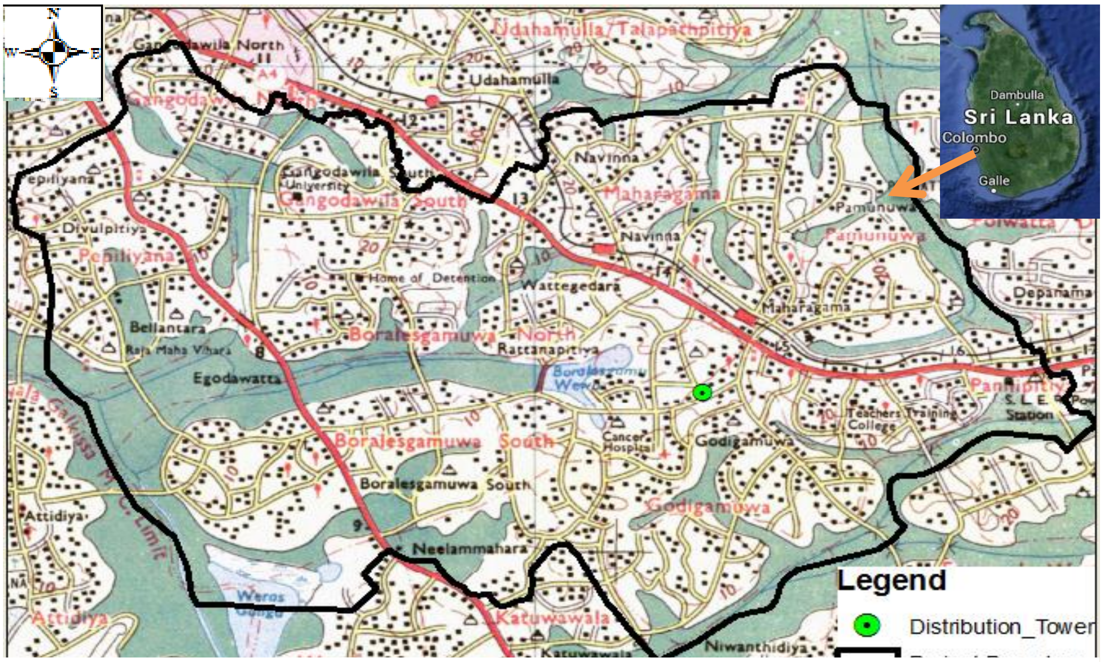

Figure 4-1 Study area map

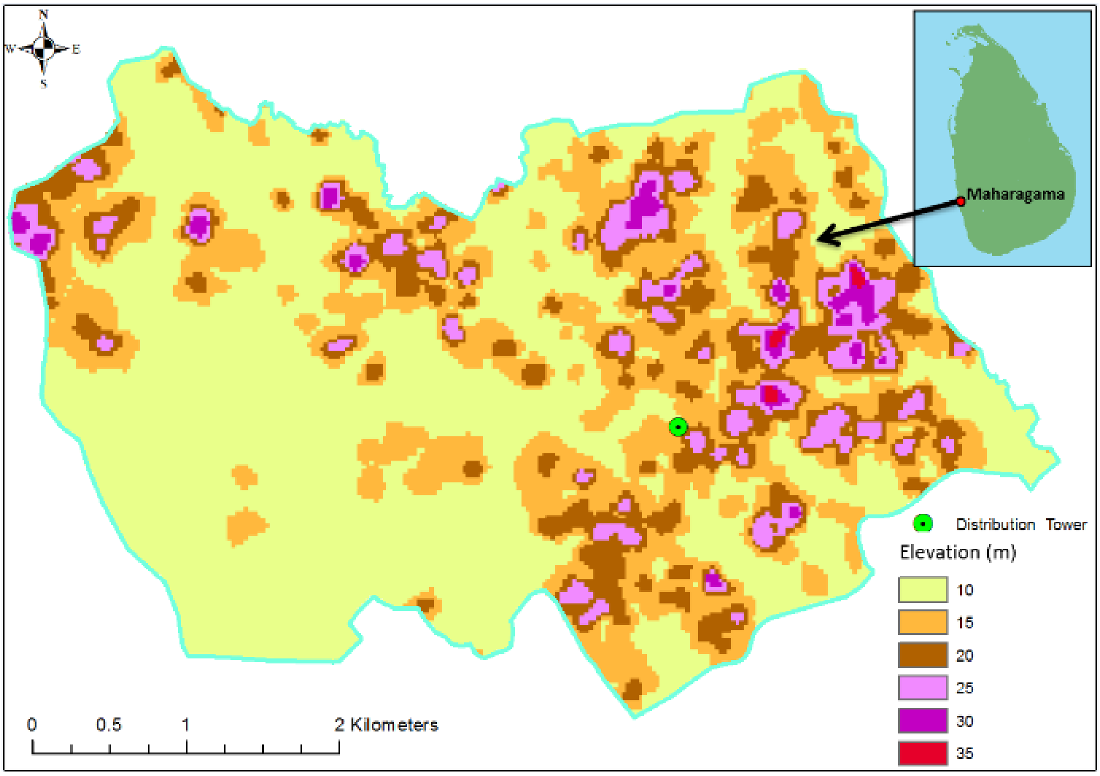

Figure 4-1(b) Maharagama area map with elevation (m MSL) details

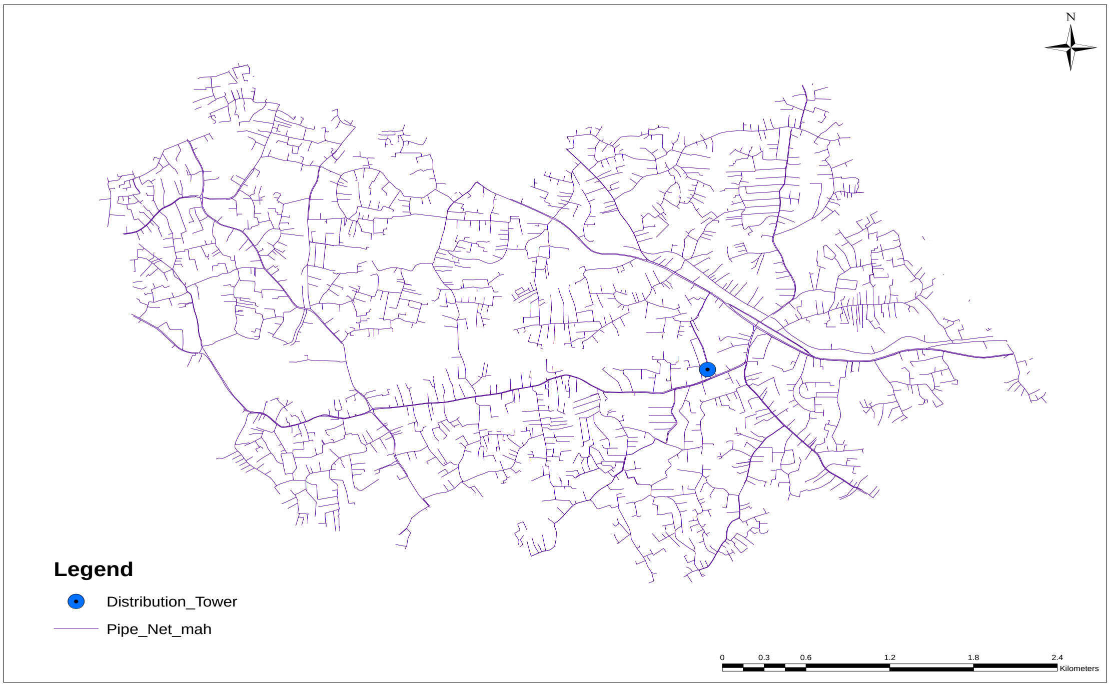

Figure 4-2 Maharagama Water Distribution Network

4.2 Data and Data Period

Historic water demand data was obtained from the National Water Supply and Drainage Board (NWSDB) based on metered data and Monthly Operating Reports. In order to represent monthly variation of the demand, monthly usage of domestic and commercial consumers of 15 years from January 2000 to December 2014 were collected from the billing system maintained by NWSDB, for Maharahgama water supply scheme. Daily inflow and daily pumping data were collected from the Maharagama regional support center. That data was available from 2005 to 2014.

It is believed that the consumption has a monthly and weekly variation. Hence, hourly pumping data, 10-minute resolution telemetry data that indicates the water levels of service reservoir were collected for five weeks corresponding to five months representing each monsoon period of the year from 2012 to 2014. From the above five months, all 7 days of one complete week (for which the most regular flow data were available) were selected and selected durations and periods are shown in Table 4-2. These data were obtained from the data base maintained by Operation and Maintenance Office at Maharagama.

Table 4-2 Data duration details for dynamic analysis

Year	Month	Date	
		From	To
2013	December	22	28
2014	April	13	19
2014	June	22	28
2014	July	06	12
2014	Aug	03	09
2014	Oct	10	16

The water supply data for the Maharagama water supply scheme and number of connections extending back to 2005 is summarized in Appendix C. Detailed monthly water use for all customers for Fiscal Years 2000 through 2014 is provided in Appendix C.

Using this data, the following parameters have been estimated: Average day demand, which is the average daily water use for the year; Maximum day demand, which is the highest daily use for the year; and Peak hour demand, which is the estimated maximum hour of water use during the year.

4.3 Data Checking

Available data requires checking prior to any analysis. Data were checked for missing periods and visual examinations were also carried out. Consumption data were checked against inflow data and the difference was compared with the Non-Revenue Water (NRW) percentage calculated by NWSDB. It shows that there exists no significant deviation of data. Abnormal deviations of monthly consumption were observed during visual data checking and the identified erroneous values of monthly usage were corrected by distributing off through respective months. Data from some selected years found to be not reliable were removed from the study data set. Data from year 2000, 2001 and part of year 2002 were removed, accordingly. This error may be due to still growing number of connections in early years just after commissioning the system. Figures 4.3 and figure 4.4 show some important and distinct results of preliminary data analyses.

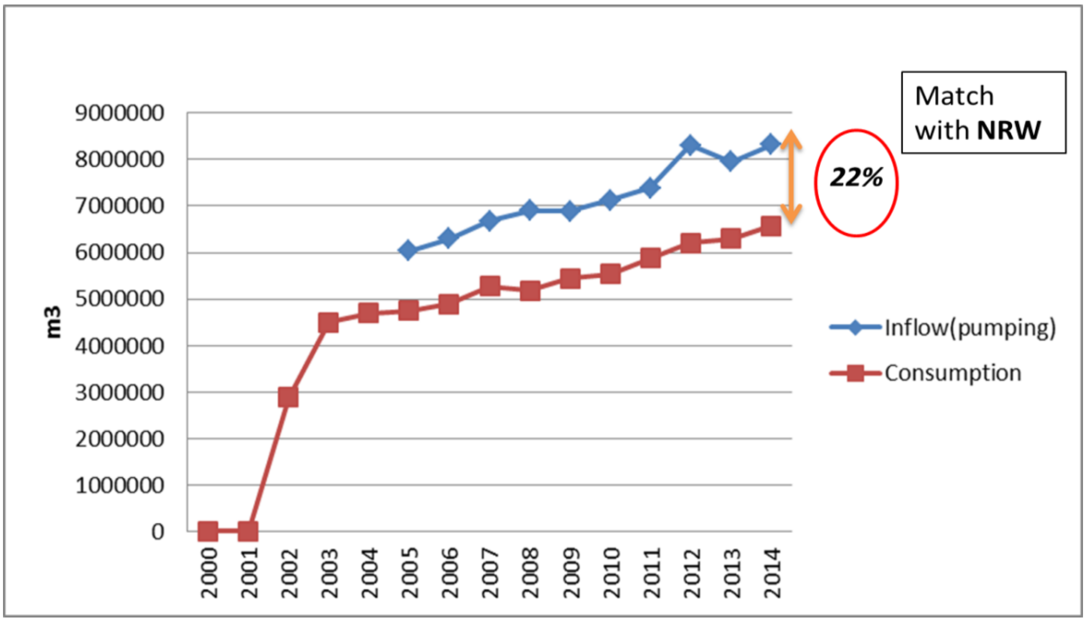

Figure 4-3 Annual consumption comparison with inflow for Maharagama WSS

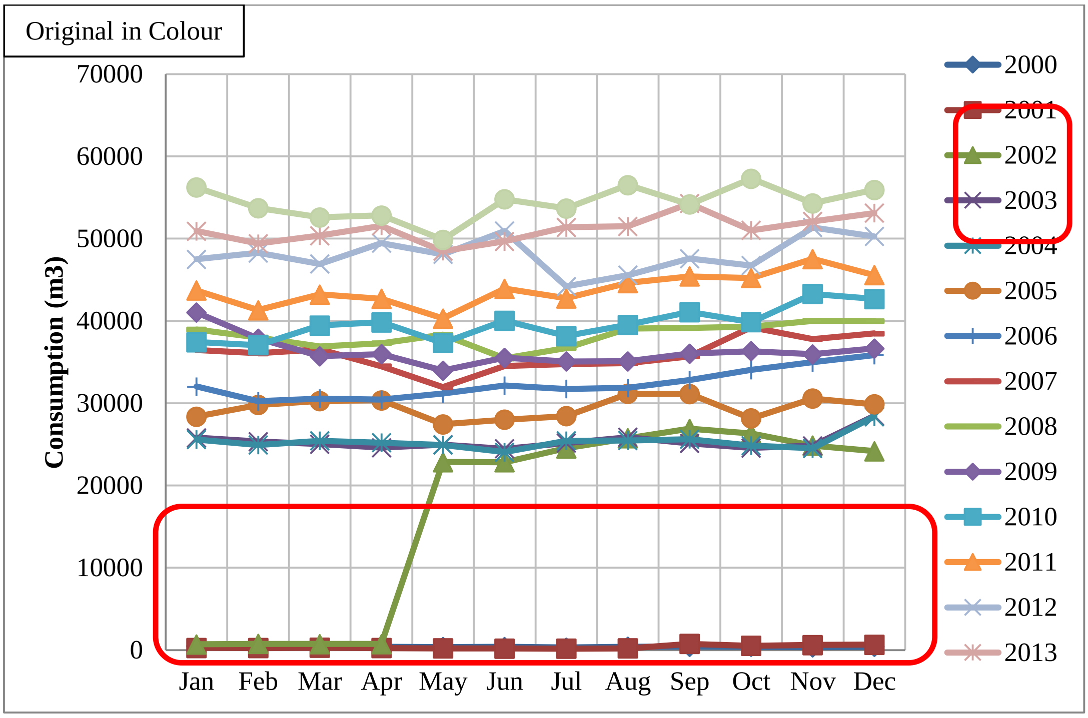

Figure 4-4 Monthly consumption comparison of 15 years for Maharagama WSS

5 RESULTS AND ANALYSIS

5.1 Monthly Consumption

Annual consumption variation over the 15-year period was generated and a gradual increase of the annual consumption is observed probably due to expanding of the system and increase in number of connections. Further analysis was needed to arrive at a definite conclusion. Therefore, consumption was generalized by considering the number of connections into account and consumption per connection variation over the period was derived. Figure 5.1 shows the annual variation of consumption from 2002 to 2014 for Maharagama water supply scheme.

Original in Colour

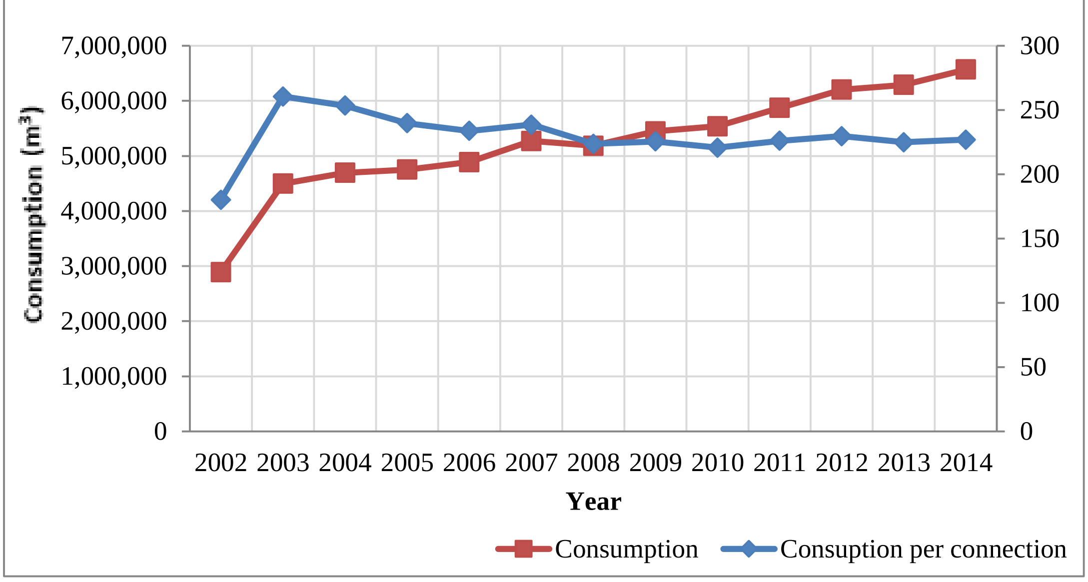

Figure 5-1 Annual consumption variation of Maharagama WSS

Monthly consumption variation over the considered period was analysed using the generalization of per connection consumption. It does not show any significant pattern over the year. This analysis was performed seperately for domestic and commercial consumer categories as well in order to identify the variation with the type of consumers. Envelope of monthly variation of consumption for domestic users and commercial users were obtained using statistical analysis described in Methodology chapter. Figures 5.2 and 5.3 show monthly consuption variation of years 2002 to 2014 for domestic and commercial consumer categories, respectively. Enevelope of monthly variation for domestic and commercial categories shown in Figures 5.4 and 5.5, respectively.

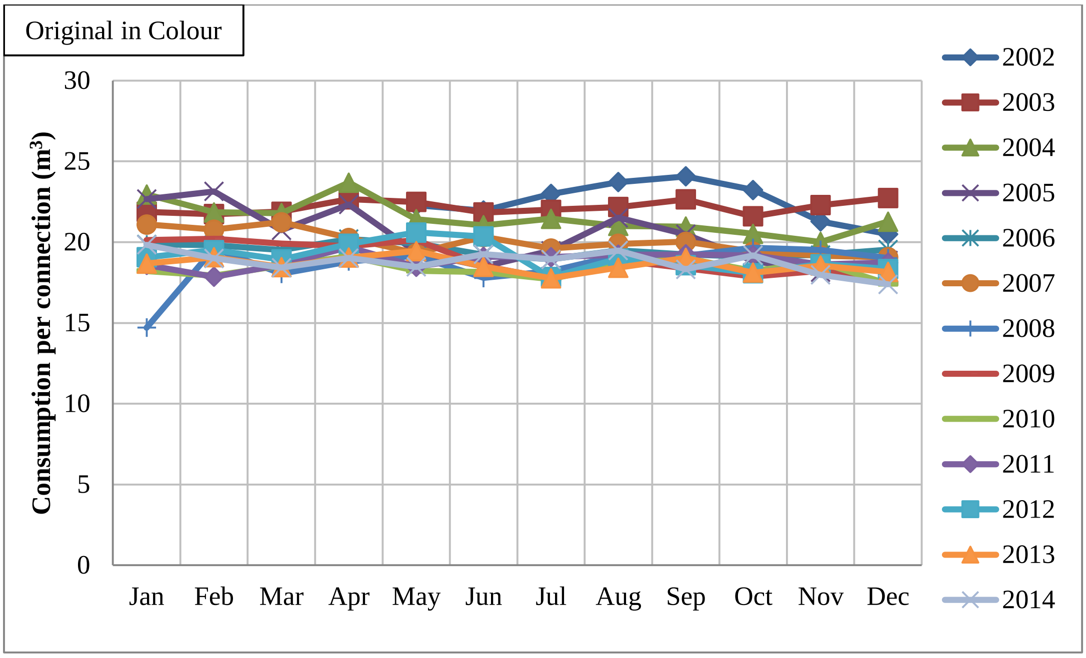

Figure 5-2 Monthly domestic per connection consumption variations in Maharagama WSS

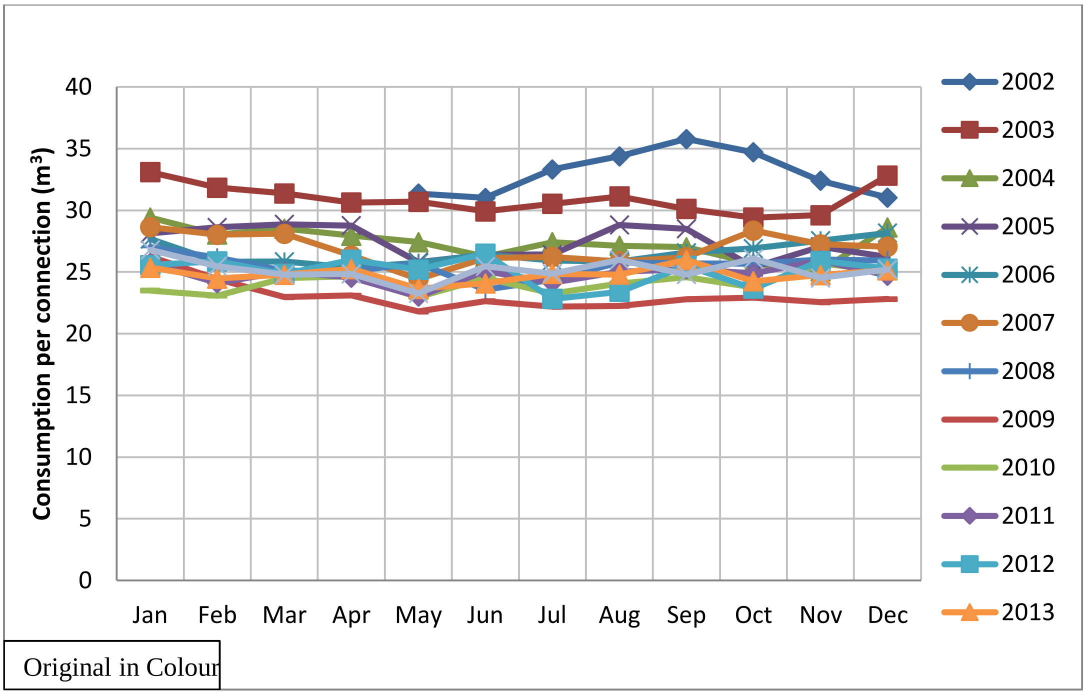

Figure 5-3 Monthly commercial per connection consumption variations in Maharagama WSS

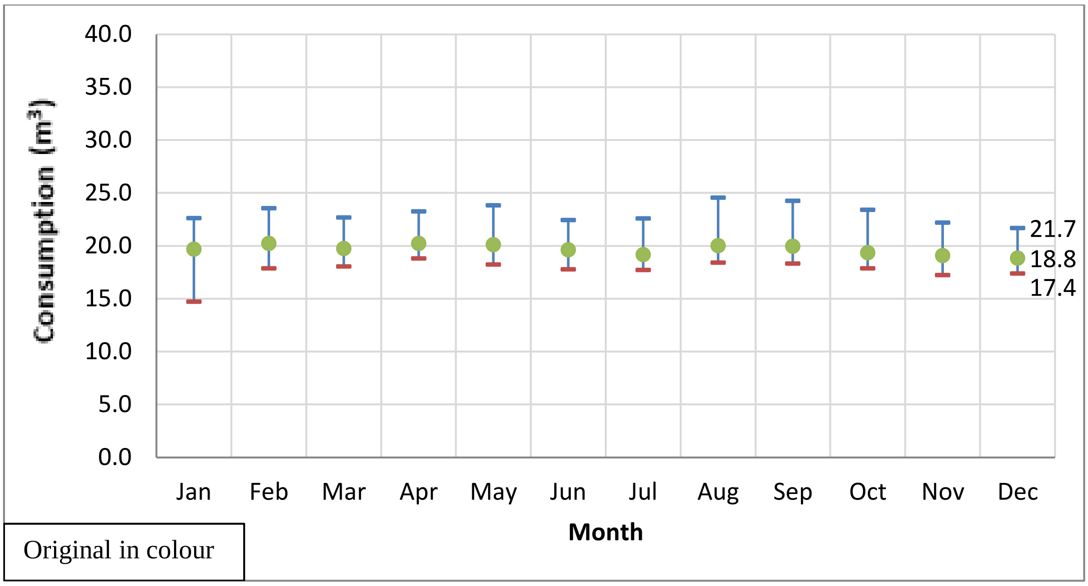

Figure 5-4 Monthly consumption variations – Domestic category

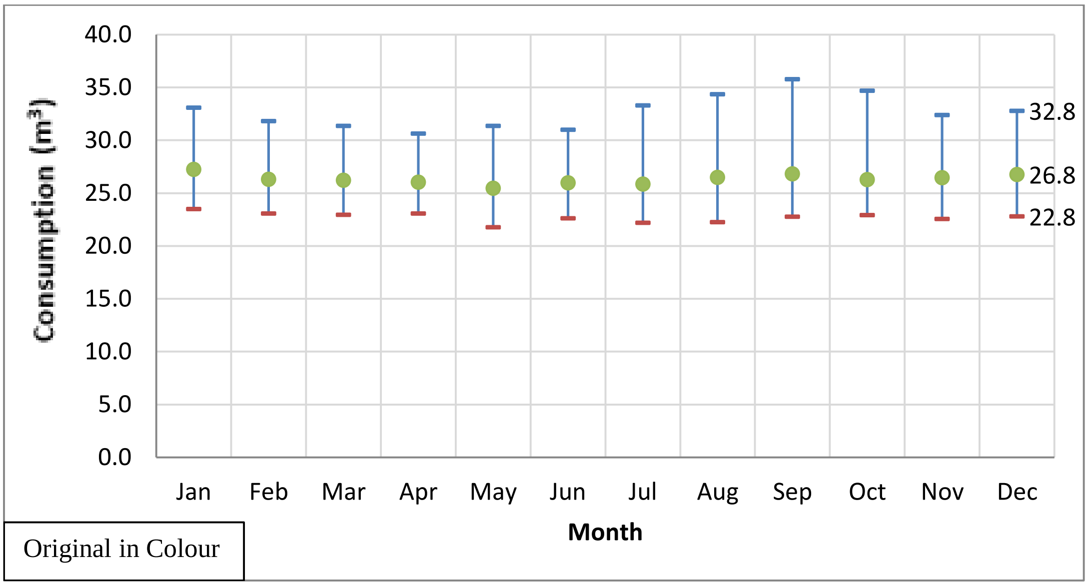

Figure 5-5 Monthly consumption variations – Commercial category

5.2 Level of Service

Consumer complaints data were analysed based on dockets using GIS application. Spatial distribution of complaints per connection was mapped and shown in Figure 5.6. Three classes have been established based on complaints per connection value and sample areas were selected including samples from all three classes (Figure 5.7).

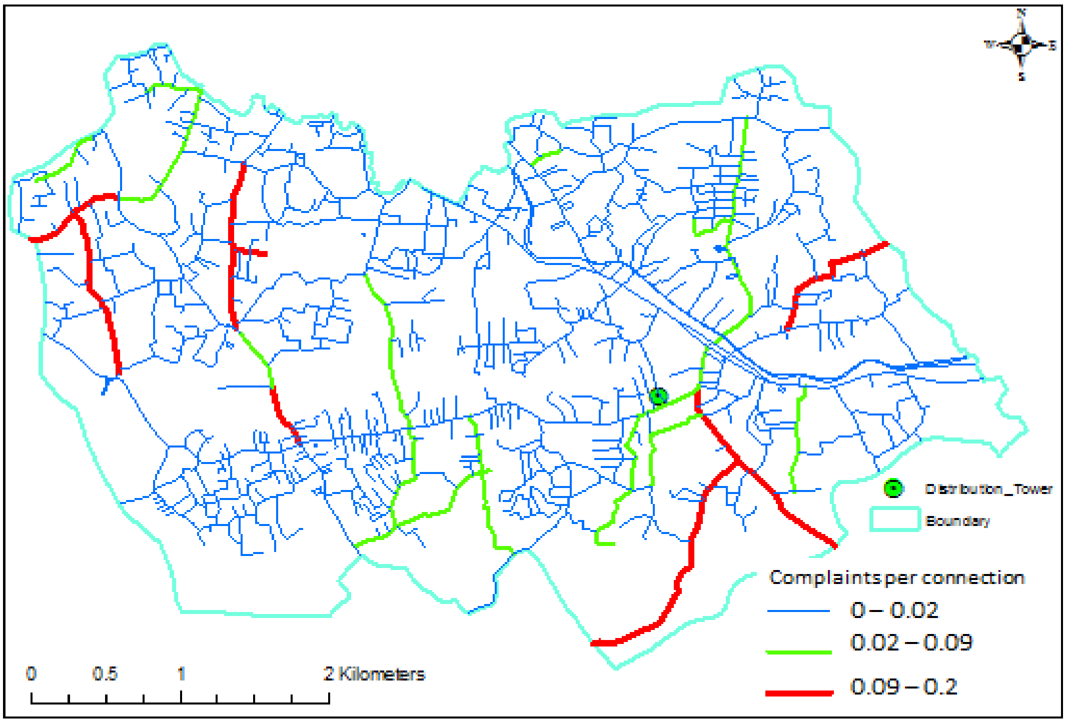

Figure 5-6 Spatial distribution of consumer complaints

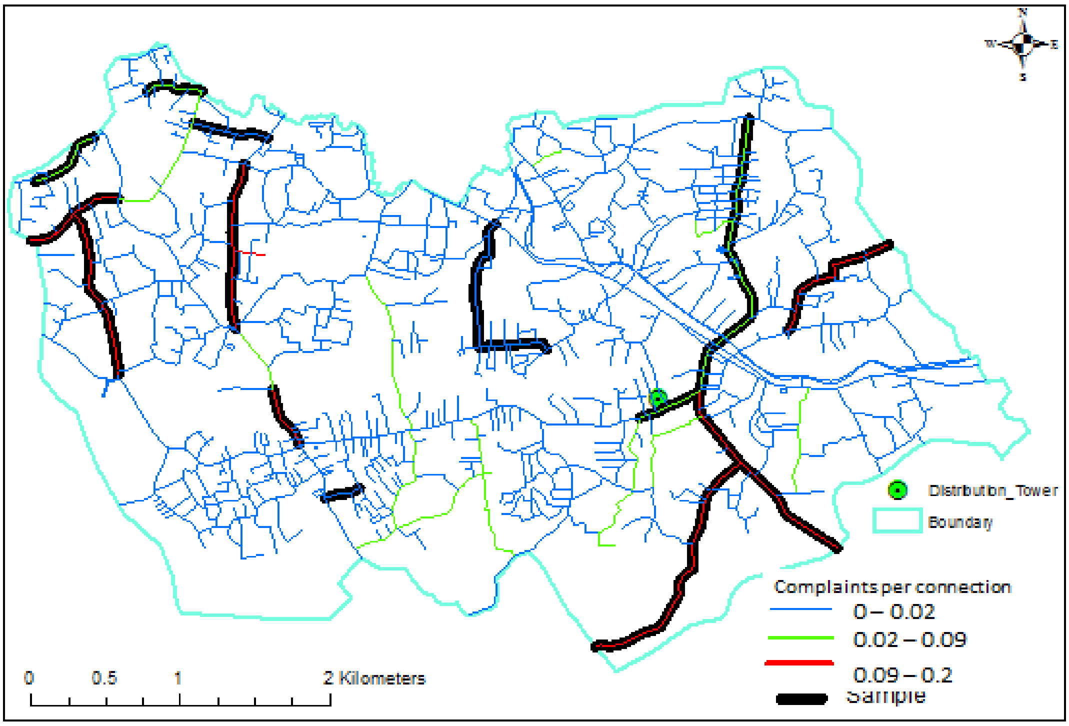

Figure 5-7 Sample selection of study

Monthly consumption per connection was studied for selected sample areas while keeping control areas and critical areas together. Observed variation is shown in Figure 5.8. Then the control and critical samples were separated and compared and the results are shown in Figure 5.9. The considered duration was then divided in to two periods and the same analysis was performed in order to compare temporal variation of control and critical sample areas. Temporal variations in 'consumption per connection' of sample areas are shown in Figure 5.10. and Fig 5-11

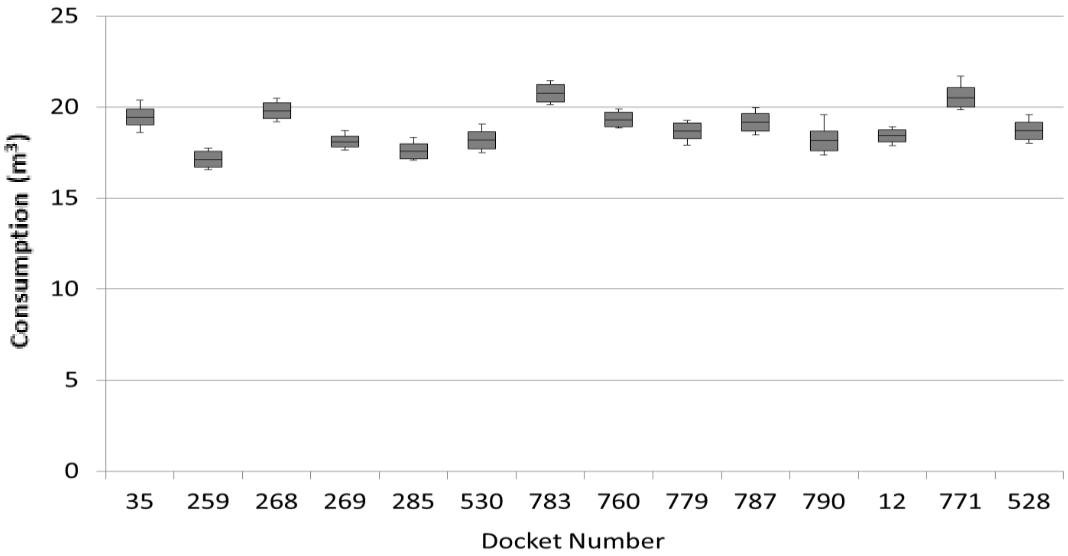

Figure 5-8 Variation in consumption variation for sample dockets

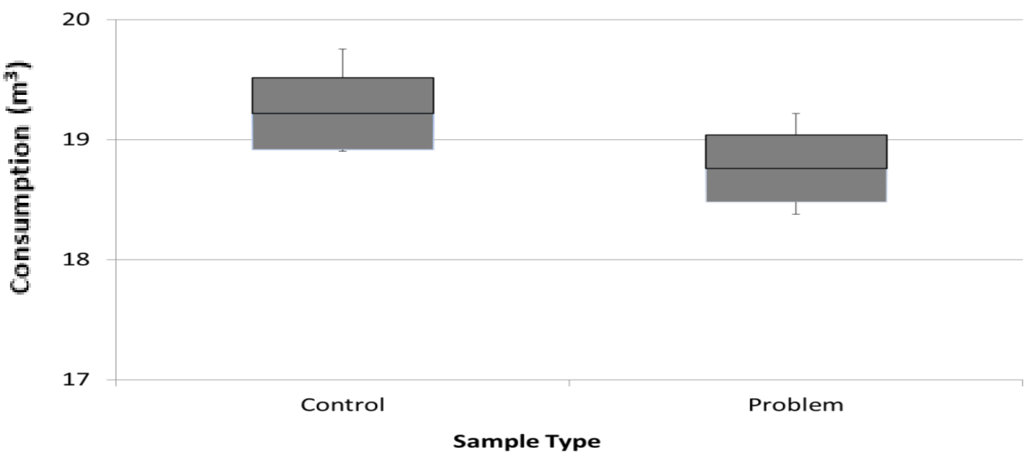

Figure 5-9 Comparison of variation in consumption with the level of service

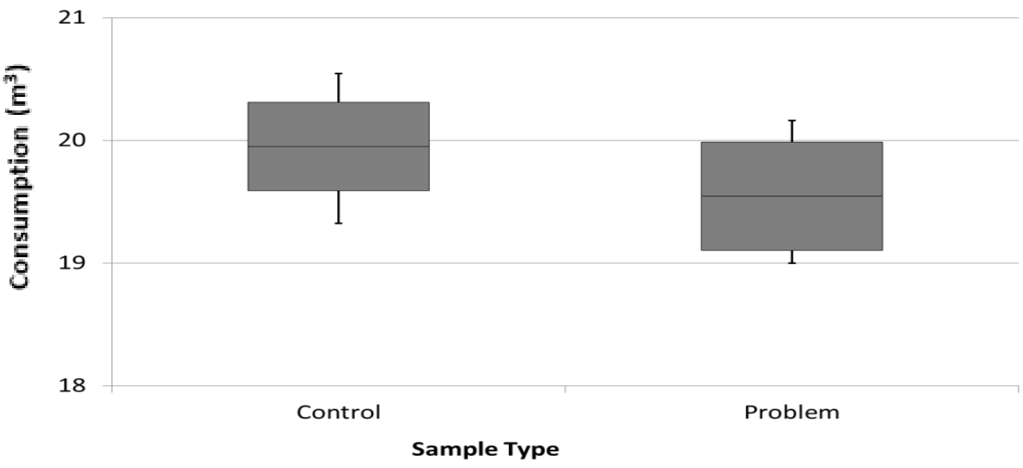

Figure 5-10 Variation in consumption with the level of service for first six years

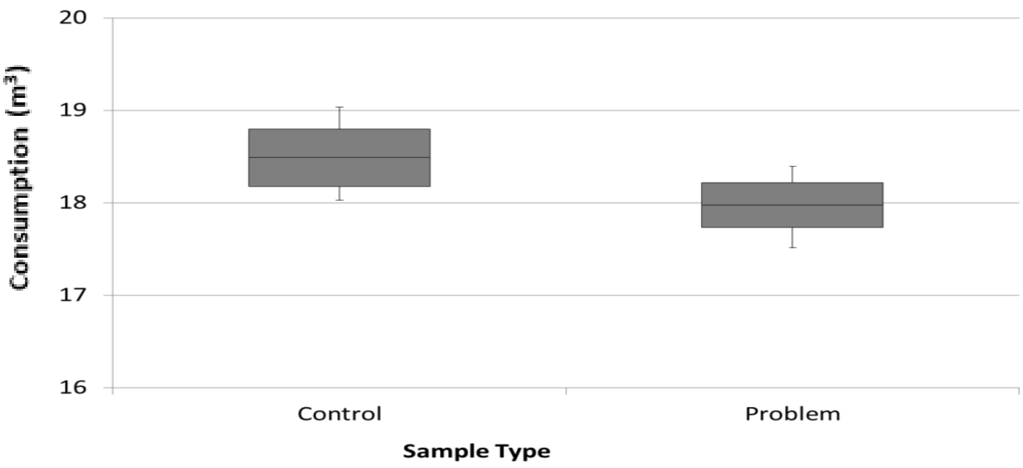

Figure 5-11 Variation in consumption with the level of service for last six years

5.3 Critical parameters to study level of service

Proposed parameters to study relationship towards level of service were tabulated and analysed using Principal Component Analysis (PCA). The evaluated parameters or components of the PCA are tabulated in Table 5.1 and the results of the analysis are shown in Table 5.2 and Figure 5.12. However, when all proposed parameters are considered, a distinct relationship could not be observed. Further study was carried out on two selected critical parameters, Elevation and Distance, which shows a definite relationship as per the tabular analysis.

Table 5-1 Docket wise distribution of proposed parameters

Docket	complaints	Pipe Diameter (mm)	Connection	Complaints per connection	Length (km)	Connection Density	Distance (km)	Avg Elevation (msl)	Min Elevation (msl)	Max Elevation (msl)	Maximum Head Available (m)
12	0	110	148	0	1.42	104.41	2.13	13.00	10	20	8.78
35	20	160	444	0.05	1.74	254.67	1.75	18.01	10	35	15
259	33	90	301	0.11	1.03	291.79	1.79	23.30	15	35	9.4
268	20	400	225	0.09	0.75	298.97	0.09	16.56	15	25	28.6
269	30	110	240	0.13	1.49	161.36	1.05	15.04	10	25	18.8
285	42	90	303	0.14	1.79	168.84	1.82	14.69	10	30	8.6
528	0	110	128	0	0.25	521.92	3.21	10	10	10	18
530	13	225	113	0.12	0.43	261.15	2.87	10	10	10	35.4
760	24	110	127	0.19	1.16	109.07	4.15	11.20	10	15	34.14
771	0	90	154	0	0.52	296.44	5.30	11.10	10	15	34.45
779	44	90	489	0.09	0.40	1233.24	5.28	11.18	10	15	34.15
783	22	110	118	0.19	1.20	98.22	4.83	14.25	10	25	31.09

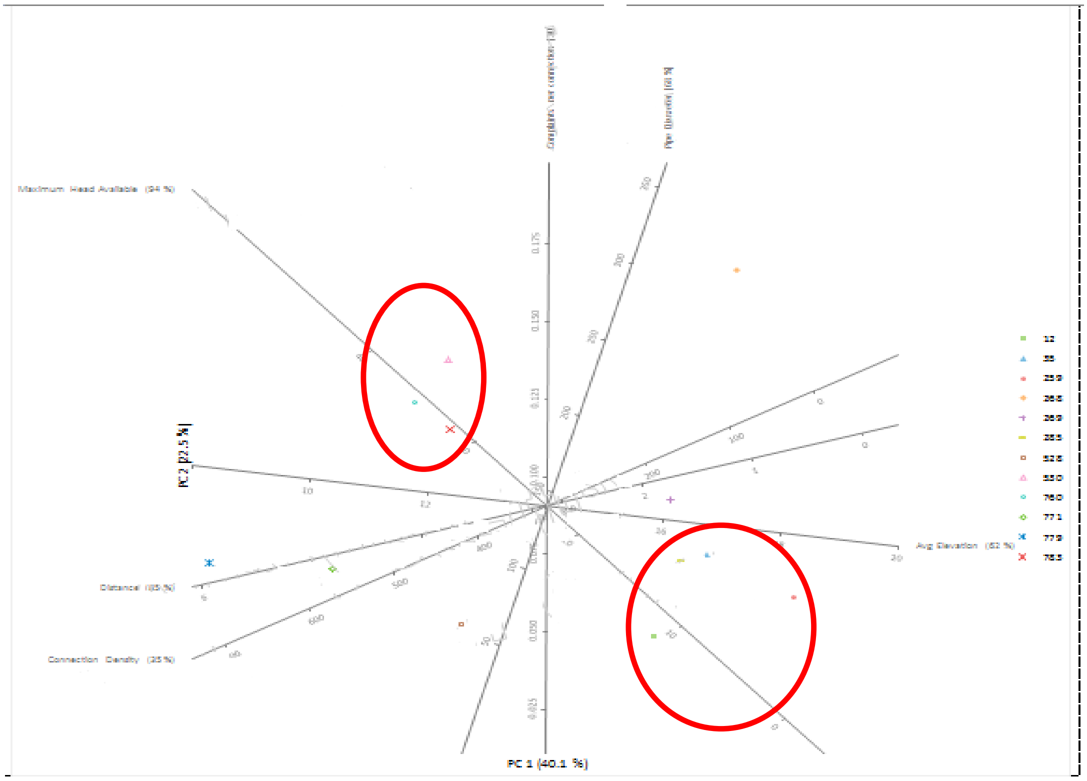

Figure 5-12 PCA biplot of analysed parameters and identified clusters

Table 5-2 PCA Analysis Results Table

Coefficients

	Component					
	1	2	3	4	5	6
Pipe Diameter	0.194	0.663	-0.513	0.021	0.082	-0.503
Complaints per connection	0.003	0.475	0.703	0.323	-0.395	-0.141
Connection Density	-0.357	-0.184	-0.394	0.772	-0.297	0.005
Distance	-0.583	-0.160	0.243	-0.008	0.449	-0.611
Avg Elevation	0.506	-0.069	0.165	0.547	0.639	0.063
Maximum Head Available	-0.489	0.521	-0.031	0.022	0.373	0.591

Distance from the service reservoir (Pipe length) and elevation of the considered location show a significant effect towards level of service. Out of seven problem areas, in six areas, a threshold value for the elevation could be observed whereas distance does not show such limits. Sample problem area "268" out lied with elevation threshold. Combined effect of both distance and elevation were studied for identifying further relationships, if any. Threshold level for combined effect of Elevation and Distance can be observed for determining the level of service and from the sample areas, three problem areas (268, 269, and 530) were identified to be outliers. These three areas identified as outliers could have other parameter effects determining their level of service rather than distance and elevation. The analysis results are shown in Figures 5.13 and 5.14.

The effect of pipe diameter was then studied and it is observed that those outlying areas (268, 269, 530) from the Elevation and distance combined threshold have relatively higher pipe diameters than others. Hence, it is presumed that the diameter effect is more significant for those areas and contributes more towards the level of service in the area. Figure 5.15 shows the variation of pipe diameter over the sample areas. Further study on other parameters such as connection density, network configuration and available pressure head in the system would be required for deriving more accurate and firm conclusion on the effect of these parameters to the level of service. In this present study, only the effect of elevation, distance and pipe diameter were considered.

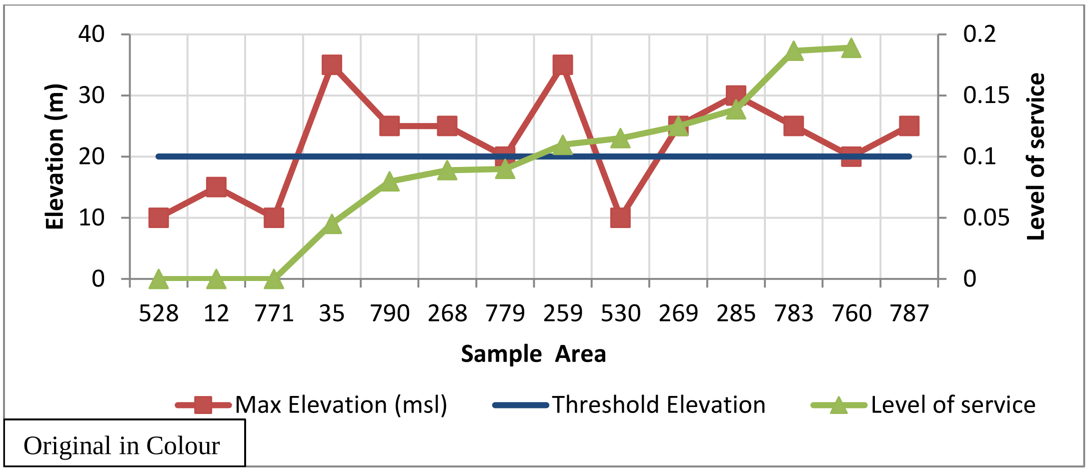

Figure 5-13 Elevation effect on level of service

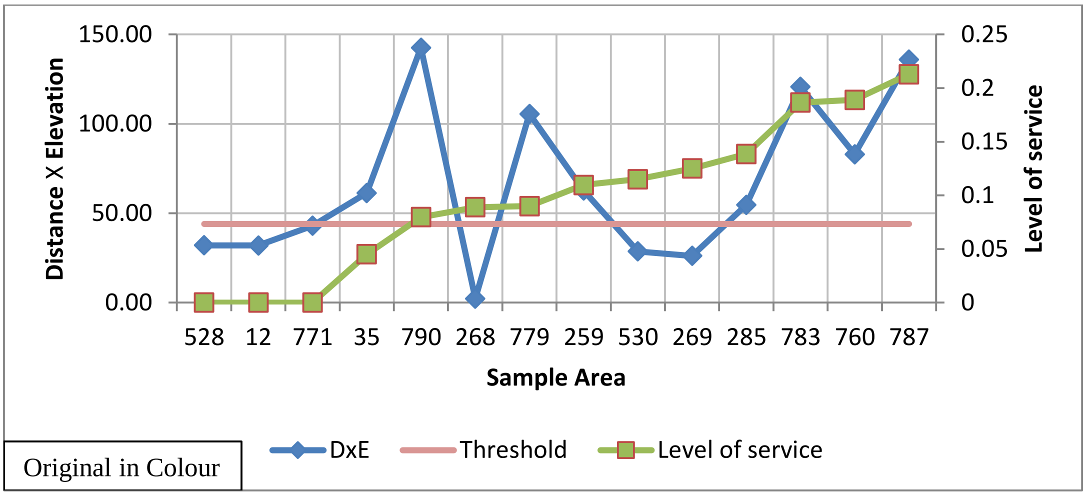

Figure 5-14 Combined effect of Distance and Elevation on level of service

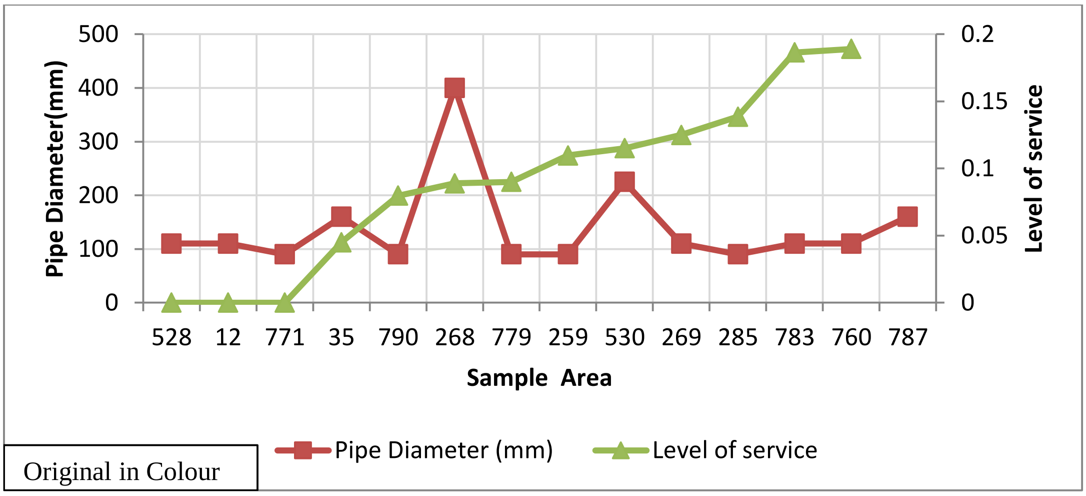

Figure 5-15 Effect of pipe diameter on level of service

5.4 Weekly Analysis

In order to study the weekly variation of consumption, analysis was carried out considering selected data over a five-week period. The upper and lower limits derived from the statistical analysis (i.e. Small Sample Theory) are less reliable due to the very small sample size (5 weeks). Hence, for the calculation of Daily Peak Factor (DPF), the method used by De Silva (2011) was used. In this analysis, the upper confidence limit is considered to be the maximum possible outflow readings in any given time with 95% confidence level. The whole set of maximum values eventually form the day of maximum consumption for the entire sample subjected to the statistical analysis. Similarly, the average limit gives the average day of consumption pertaining to the same period (De Silva, 2011). Daily peak factors were calculated considering upper limit value and the average value shown in Table 5.3.

Table 5-3 Calculation of Daily Peak Factor

Day	Dec-13	Apr-14	Jun-14	Jul-14	Oct-14	Mean	S	tc	95% confidence limit	Upper bound	Lower bound	DPF
Sun	1058.5	982.7	987.1	1012.0	989.3	1005.9	31.5	2.13	33.53	1039.5	972.4	1.08
Mon	834.9	995.2	916.6	1052.1	1035.0	966.8	90.3	2.13	96.21	1063.0	870.5	1.10
Tue	702.0	972.8	972.4	944.3	1027.3	923.8	127.6	2.13	135.86	1059.6	787.9	1.10
Wed	846.0	944.4	1027.7	1007.6	1036.2	972.4	79.3	2.13	84.43	1056.8	888.0	1.09
Thu	811.4	914.9	1014.0	990.7	1060.5	958.3	97.5	2.13	103.87	1062.2	854.4	1.10
Fri	858.0	978.9	1019.5	997.5	1040.9	978.9	71.5	2.13	76.17	1055.1	902.8	1.09
Sat	876.8	1023.1	955.8	942.1	967.4	953.0	52.6	2.13	55.99	1009.0	897.0	1.04
						965.6						

5.5 Dynamic Analysis for Diurnal Variation

Dynamic Analysis was carried out based on the 10 minute resolution service reservoir level data and pumping data by performing a water balance calculation to the service reservoir. Results were plotted and shown in Fig. 5.16. Diurnal variation of demand was obtained after following statistical analysis by means of Large Sample Theory (De Silva, 2011) on the water balance calculation results. Table 5.4 shows the result of statistical analysis while Fig. 5.17 shows Diurnal variation obtained through statistical analysis.

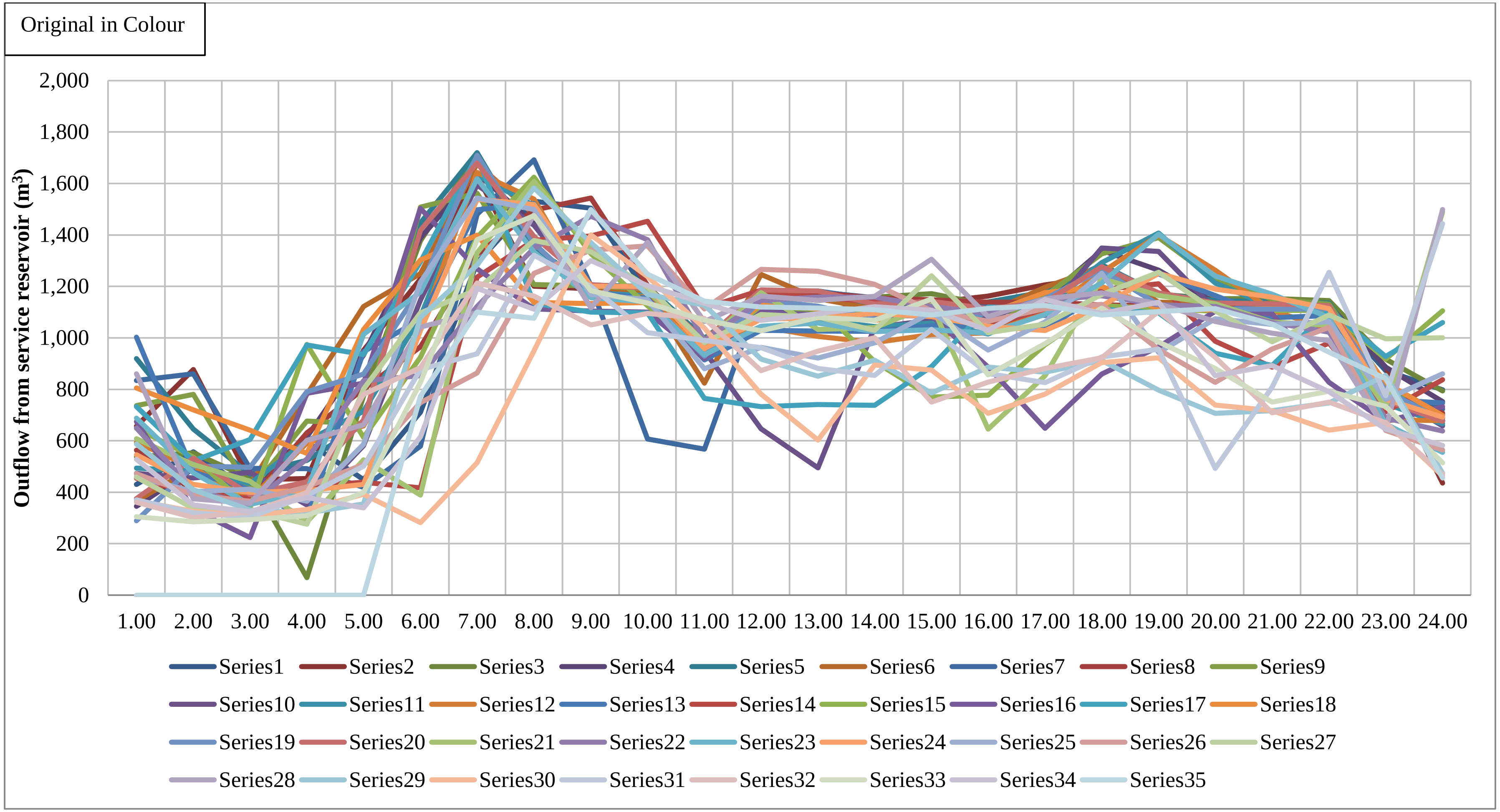

Figure 5-16 Diurnal flow variation of 35 selected days

Table 5-4 Calculation of Hourly flow factor

Time	Average flow (m^3/hr)	Std Dev	95% confidence limit	Upper limit	Lower limit	Envelope	Flow Factor
1:00	548.4	183.3	61.6	622.0	498.8	498.8	0.5
2:00	469.4	148.3	49.9	528.8	429.1	429.1	0.4
3:00	399.1	84.3	28.3	424.9	368.3	368.3	0.4
4:00	500.7	200.8	67.5	564.0	429.0	429.0	0.4
5:00	682.0	217.9	73.2	748.9	602.5	602.5	0.6
6:00	1020.9	319.2	105.8	1126.7	915.1	1126.7	1.1
7:00	1392.0	280.9	93.1	1485.0	1298.9	1485.0	1.5
8:00	1370.9	179.4	59.4	1430.3	1311.5	1430.3	1.5
9:00	1247.8	127.2	42.1	1289.9	1205.6	1289.9	1.3
10:00	1172.6	130.6	43.3	1215.9	1129.4	1215.9	1.2
11:00	972.8	109.1	36.2	1009.0	936.6	1009.0	1.0
12:00	1072.6	139.5	46.2	1118.8	1026.4	1118.8	1.1
13:00	1049.7	163.9	54.3	1104.0	995.4	1104.0	1.1
14:00	1060.0	101.9	33.8	1093.8	1026.3	1093.8	1.1
15:00	1068.3	120.8	40.0	1108.3	1028.2	1108.3	1.1
16:00	1015.1	130.0	43.1	1058.2	972.0	1058.2	1.1
17:00	1063.0	132.7	44.0	1107.0	1019.1	1107.0	1.1
18:00	1160.6	128.7	42.6	1203.2	1118.0	1203.2	1.2
19:00	1145.5	143.8	47.6	1193.2	1097.9	1193.2	1.2
20:00	1056.6	166.6	55.2	1111.8	1001.4	1111.8	1.1
21:00	1030.1	142.0	47.0	1077.2	983.1	1077.2	1.1
22:00	1034.0	140.6	46.6	1080.6	987.4	1080.6	1.1
23:00	778.2	92.0	30.5	808.7	747.7	747.7	0.8
0:00	757.6	273.2	90.5	848.2	667.1	667.1	0.7
	961.2					981.5	

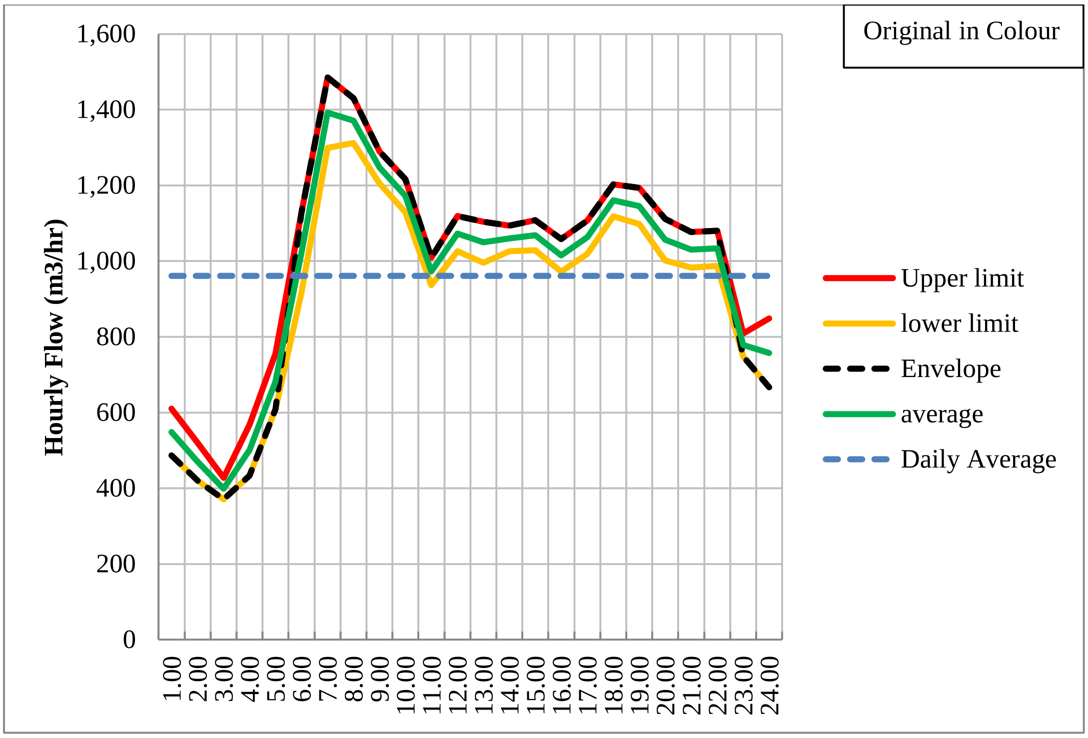

Figure 5-17 Diurnal flow variation of Maharagama WSS

Corresponding reservoir water level data were also subjected to the same analysis and diurnal variation of tank level was obtained. Statistical analysis results are tabulated in Table 5.5 and thus obtained water level variation is shown in Fig. 5.18.

Table 5-5 Analysis of Hourly water level variation

Time	Average water level (m^3/hr)	Std Dev	95% confidence limit	Upper limit	lower limit	Envelope
0	4.0	1.5	0.5	4.5	3.5	4.5
1	4.6	1.5	0.5	5.1	4.2	5.1
2	4.6	0.9	0.3	4.9	4.4	4.9
3	4.9	0.7	0.2	5.1	4.6	5.1
4	4.9	0.5	0.2	5.1	4.8	5.1
5	5.0	0.9	0.3	5.3	4.7	5.3
6	4.6	1.0	0.3	4.9	4.2	4.9
7	3.0	1.8	0.5	3.5	2.4	3.5
8	1.6	1.6	0.5	2.1	1.1	1.1
9	1.1	1.3	0.4	1.5	0.7	0.7
10	0.9	1.1	0.4	1.3	0.6	0.6
11	1.0	1.1	0.4	1.3	0.6	0.6
12	1.3	1.4	0.4	1.8	0.9	0.9
13	1.6	1.6	0.5	2.1	1.1	1.1
14	1.9	1.7	0.5	2.4	1.4	1.4
15	2.1	1.7	0.5	2.7	1.6	1.6
16	2.3	1.8	0.5	2.9	1.8	1.8
17	2.1	1.7	0.5	2.6	1.6	1.6
18	1.5	1.6	0.5	1.9	1.0	1.0
19	1.1	1.4	0.4	1.5	0.6	0.6
20	1.3	1.7	0.5	1.9	0.8	0.8
21	1.7	2.1	0.6	2.4	1.1	1.1
22	1.9	1.9	0.6	2.5	1.3	1.3
23	3.1	1.6	0.5	3.6	2.6	3.6
	2.6					2.4

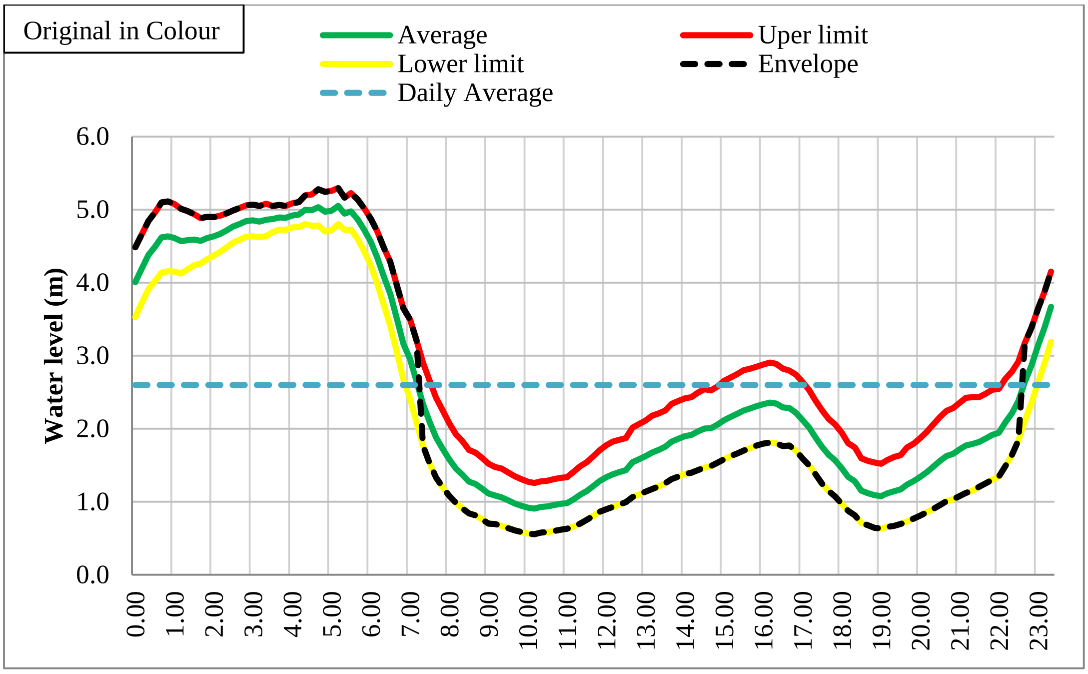

Figure 5-18 Diurnal water level variation of service reservoir - Maharagama WSS

The peak factors derived from the statistical analysis are given in Table 5.6. The values from recent studies and using for planning and design by NWSDB are included for comparison.

Table 5-6 Comparison of Peak Factors

Study	HPF	Time of Occurrence (hrs)	MNF	Time of Occurrence (hrs)
Present Study (Maharagama)	1.5	7.00	0.4	3.00
De Silva (1999) (Pannipitiya/Kaduwela)	1.8	7.30	0.15	3.00
TECD WSP (Colombo Development Project)	1.5	7.00 & 19.00	0.4	2.00 & 3.00

5.6 Field Survey

A field survey was carried out in the study area in order to verify the results obtained through the historical data analysis and the present study. Aim of this field survey was to collect information and monitor the level of service of the water supply at household level and to identify the performance at operational level across Maharagama water supply scheme area. Further, this survey was conducted by the author in collaboration with the National Water Supply and Drainage Board, Maharagama. Figure 5.19 shows spatial distribution of survey points.

Carefully designed standard questionnaires were prepared separately for the households and NWSDB operational and maintenance staff. Sample questionnaire is attached in Appendix F. Survey was carried out based on the identified sample areas, which are considered for the main analysis in this present study, and considered to adequately represent each sample category. Personnel were interviewed and questionnaires were directly filled in. Gathered information were then tabulated in the spreadsheet templates and processed.

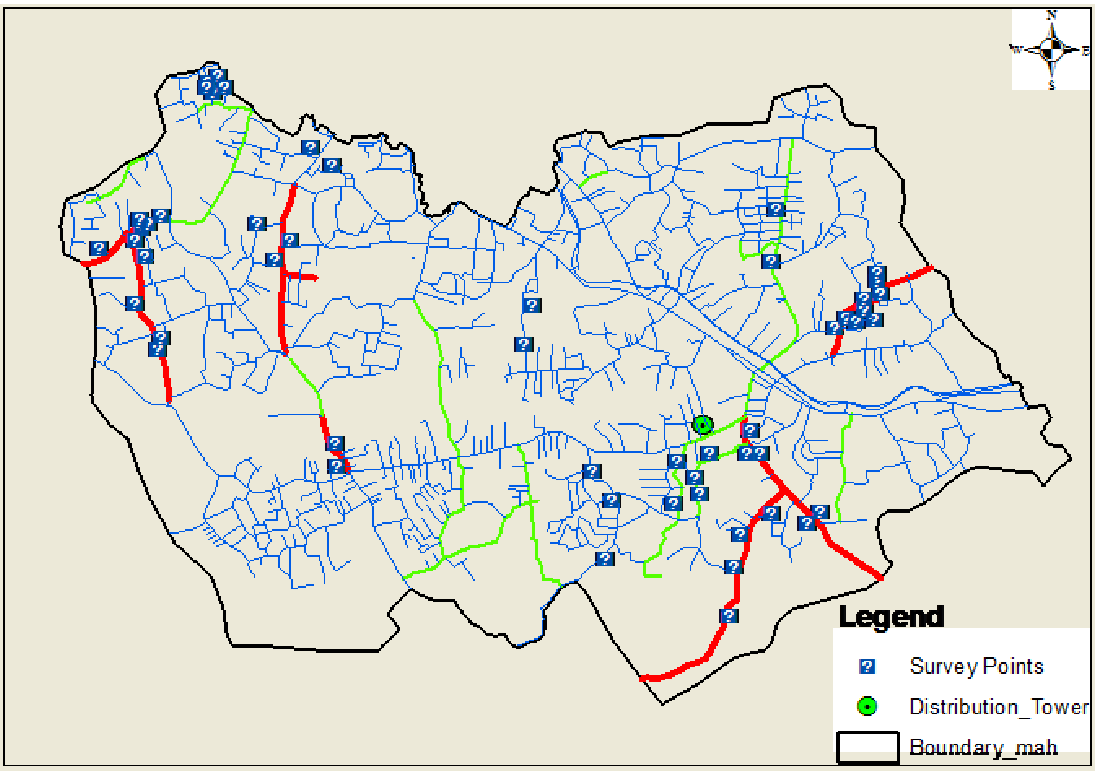

Figure 5-19 Household field survey locations map

After analyzing the survey data, it was verified that the level of service obtained through the consumer complaints to the Call centre of NWSDB is matched with the actual ground situation of the Maharagama area. Area wise comparison of level of service based on the survey data is included in Appendix F.

Then the diurnal service level was analysed by giving a score to the service level of each hour. One to four marking scheme (Likert scale) was adopted for assigning a score to the level of service. Value 1 refers to a good/satisfactory level of service, 2 refers to ok/acceptable level of service whereas 3 refers to a poor level of service and 4 means very poor level of service. Then a weightage was given to the service level score based on the affected number consumers. Total number of connections in the particular area (docket) was taken as a fraction of total number of connections in the Maharagama area. Weighted service levels represent the diurnal problem curve for the Maharagama water supply area. Poor service level means higher number of reported issues or problems. Percentage of thus derived problems for each hour of the day was derived and presented in Fig. 5.20.

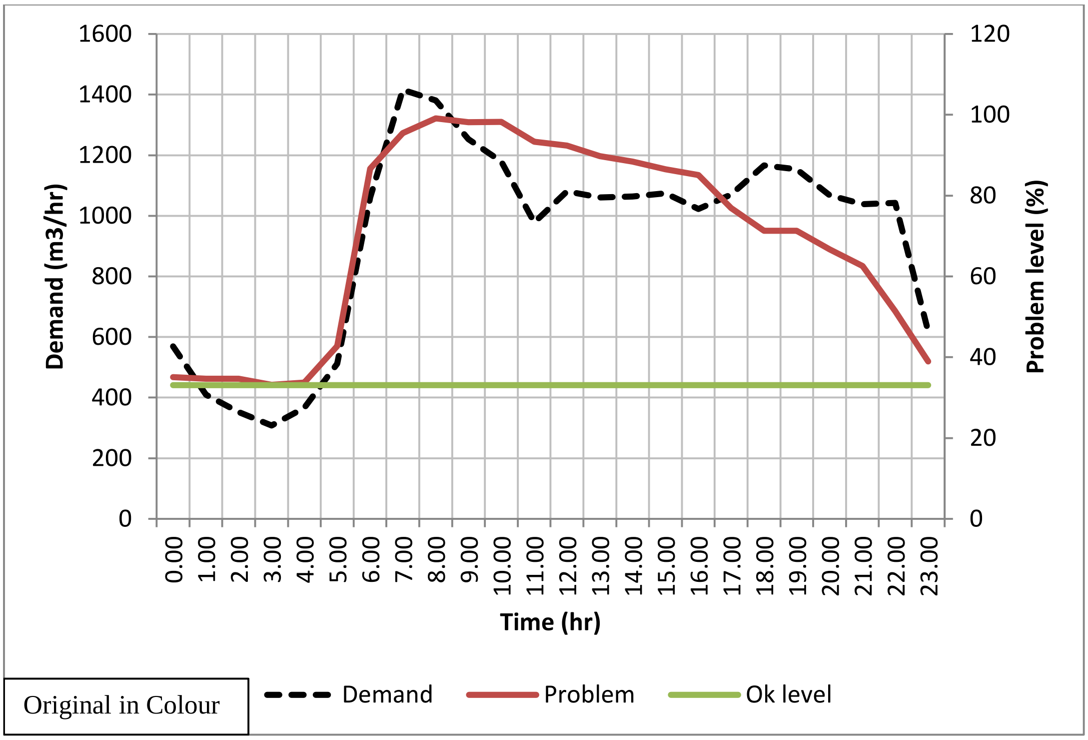

Figure 5-20 Diurnal problem level curve and the demand curve

6 DISCUSSION

6.1 Monthly Demand

A significant seasonal variation in water consumption could not be observed during this study for Maharagama area and this may be due to the prevailing tropical climate with no significant seasonal variation. Past studies also have confirmed that there is no seasonal variation in domestic water consumption in Sri Lanka (De Silva, 2011).

In addition, no monthly variation of consumption could be observed for Maharagama Water Supply Scheme. Further, two month average and quarterly average consumption were studied and any significant trend could not be observed either. This fact probably implies that people in Maharagama are adapted to a routine lifestyle throughout the year and system of supply remains constant (Rajapakshe & Gunaratne, 2005; Domene & Saurí, 2006; Jansen & Schulz, 2006). Being a tropical country, Sri Lanka does not experience significant variation in temperature during the year. A statistical analysis of water use in New York City showed that daily per capita water use on days above 25°C increases by 11 litres/°C (roughly 2% of current daily per capita use) (Angelos L. Protopapas, Sunisa Katchamart, & Alina Platonova, 2000). Hence, uniform temperature over the year could be another reason for constant water consumption pattern.

Domestic consumption as well as the commercial consumption follows no monthly patterns and did not show monthly variation in per connection consumption. In Maharagama water supply area, the domestic consumption per month per connection is 19.7±0.5 m^3. This is increased to 26.3±0.5 m^3 in commercial category of consumers. In sub-urban area, still a significant part of households is located in rural areas and it was reported that the people still use groundwater from shallow dug wells for a part of consumption. Therefore, the reported consumption is slightly lower in this particular area due to this reason.

6.2 Diurnal Demand

Significant variation of demand could be identified during the day for Maharagama WSS. Two distinct peaks could be identified and morning peak is the highest while the evening peak has been flattened. The observed consumption follows a similar pattern every day regardless of minor changes from day to day. Even during the weekends, a significant change from the week days could not be identified. Flow is minimum at the early hours of the day. This generally represents leakage and filling up of storage tanks specially in high elevated and distant areas from the service reservoir. These storage tanks are not filled up during the daytime due to low pressure in the system. This is reflected in the tank water level variation, too. Flow increases sharply as the day advances, reaching a peak value around 7:00 to 8:00 a.m. Afterwards of this, the consumption drops down. Consumption again rises slightly during early hours of the night as people use more water when they return home. However, this peak did not grow as expected and as it should have been as seen in the beginning of the rising limb. This observation implies that evening demand has not been met up to the level of morning demand by Maharagama WSS and the supply is immaturely curtailed. Then the consumption gradually drops to a minimum towards midnight and early hours of the next day.

Peak is less even with high water level in the balancing tank implying that mid-day peak is not that significant for Maharagama WSS. The hourly flow oscillates within almost similar minimum levels (MNF) and maximum levels (HPF).

6.3 Level of Service

Diurnal problem curve derived from the field survey data indicates that there is a significant problem level, which is more than 40%, during the day. Only during early hours, there is a low problem level and thus a good service level prevails during this period. When the demand increases, the problem level is also increased. In that sense, Maharagama peak water supply demand is not fully met even during the morning peak hours. Furthermore, the morning peak is as high as 1.5, and highest problem level is also recorded at that time. That indicates the un-catered demand at the peak time. Hence, the obtained curve can be considered as a representative consumption pattern of the Maharagama area and obviously not the demand pattern.

Maharagama WSS is a fairly old and large system. The age of the original system is approximately 18 years. The distribution system has been subsequently expanded in order to keep pace with the ongoing development. The system operates at a low HPF value of 1.50, moderate MNF of 0.40 and DPF of 1.10. According to the statistical analysis, HPF of 1.50 occurs at 07.00 hrs. There is a less prominent peak flow of 1.20 at 18.30 hrs. The DPF is at 1.10. Moderate MNF of 0.4 indicates that there is significant flow during the mid-night and early morning. This may be due to the filling up of domestic storage tanks and leakages. That also on the other hand indicates that there is a possibility of large number of domestic storage tanks in the area and system is less reliable in consumer point of view.

The distribution system possibly is of domestic nature. High HPF, Low MNF are inherent properties of a system where the consumption is mainly domestic (De Silva, 2011). Very low evening HPF of 1.20 could be due to the insufficiency of the hydraulic capacity of the distribution system. The system can meet only a HPF of 1.20 during the evening peak and the remaining quantity of water is delivered through the enhanced flow during lean hours. A survey conducted in most part of the distribution area revealed that a large number of households maintain their own storage tanks. Some of low-pressure areas receive water only in the night.

As a management option, the consumers can be educated to keep domestic storage tanks and use water from the system during off peak hours such as early hours of the day and use domestic storage water during the peak hours. This may lead to a significant improvement in the service level during the peak hours. This concept can be implemented through a tariff revision by adopting time based usage metering of consumer supplies. If they use water during off peak hours, they will be charged less than that of peak hour rates.

High HPF and DPF values generally indicate high service levels with high consumer satisfaction. High DPF values cater for the maximum day demand and high HPF for the maximum hourly demand without imposing any restrictions at the consumers’ end. On the other hand, very low HPF and DPF values indicate a drop in the service levels. Therefore, it is clear that a sufficient HPF and DPF should be maintained in the system to ensure a satisfactory service level. In order to achieve this goal, the existing systems operating at very low HPF and DPF values should be augmented to improve the supply

(De Silva, 2011). Under such augmentation, the availability of water at the service reservoirs should be increased. Pump capacity as well should be increased in tandem. The capacities of the service reservoirs should also be increased if necessary, to allow for the increased rates of withdrawals during peak hours. The distribution system should be reinforced to convey the increased demand to the consumers living in all parts of the service area without inconvenience.

The reduced HPF and enhanced MNF will result in a flatter demand curve. Such distribution system has following disadvantages.

There could be a reduction in service levels towards the end of the design period. As the hydraulic capacity of the system is limited, the elevated areas in the far and will be subjected to low system pressures. This will reduce the quantity of water supplied to these areas during peak hours. In extreme cases, these areas may not receive any water and may undergo negative pressures. This may cause reverse flow of contaminated groundwater into distribution system through improperly made joints or leaks (Teunis et al., 2010; De Silva, 2011).

After a certain years of operation, the consumers in these areas are compelled to construct domestic storage tanks. These storage tanks will impose an additional cost on the consumer and create a risk of pollution.

After a long term shut down, the system takes a long time to stabilize due to reduced carrying capacity of the pipes and the large domestic storage.

Level of service shows significantly low in high-elevated areas above 20 m MSL for the Mahragama WSS area. From the identified problem areas of Maharagama, except one location, elevation has a significant effect on service level. Distance also indicates to having an effect but threshold value could not be identified. When the combined effect of elevation and distance is considered, there is a threshold value of 44, which can be identified for deteriorated level of service. There are three outliers from this threshold from the identified seven problem areas. Those three outliers indicate a higher pipe diameter than others and pipe diameter can be a governing parameter in determining the level of service for these areas. For this present study, only three parameters have been considered to have an effect on level of service, namely Pipe diameter, Distance and Elevation. There can be a combined effect of these three factors and more details of the level of service and their combined impact should be further studied.

Low level of service areas show less per connection consumption than in other areas. That may imply the restrained supply to those areas. Observation of usage data over the last 6 years shows greater decrease in level of service than during the first 6 years, and this can be due to higher demand and high connection density.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

1. System Water Balance study for service reservoir and/or sample consumer survey alone is capable enough to identify major deficiencies in the water distribution network.
2. Elevation, distance and pipe diameter have a considerable effect on determining the Level of Service (LOS) in a water supply scheme.
3. Service level has a significant effect on consumption quantity and it is more significant in the latter six year period.
4. There is no monthly consumption variation observed in Maharagama Water Supply Scheme as a whole and for domestic and commercial categories, separately as well.
5. The diurnal flow curve observed is actually not representative of the real demand of the Maharagama WSS area. It can be interpreted as the present consumption pattern as the demand is not fully met.
6. Comparatively, Maharagama consumption pattern has a two-peak variation and Colombo consumption pattern follows a three-peak variation.
7. Morning peak occurs at the same time at 07.00 hrs for both Colombo and Maharagama whereas evening peak has been shifted by one hour early at 18.00 hrs for Maharagama WSS.
8. There is a considerable level of problems on water supply service during the day, especially during the peak hours, for Maharagama WSS Area.
9. This type of study is very important prior to a comprehensive system upgrade or augmentation in order to plan for better results and improved service levels as well to derive design guidelines for new distribution network systems.

7.2 Recommendations

This study should continue to cover the comparatively old systems in Colombo and outstations. Such studies are helpful and essential to understand the behaviour of the systems and to check the effectiveness of the design. This also helps to plan the augmentation work and to develop design guidelines for the forthcoming schemes of similar nature.

The new systems must be continuously monitored for DPF, HPF and MNF values. Studies should be carryout to assess the level of consumer satisfaction simultaneously, so that a correlation could be established between the consumer satisfaction and the said parameter threshold values. Such continuous studies will help to identify the correct time for augmentation of the system. The threshold values of DPF, HPF and MNF prevailing at that point will help the Design Engineers to plan for the required augmentation and to develop design criteria for future water supply schemes.

Focus should be made to zoning of the distribution system based on critical parameters identified on level of service and threshold values of technical parameters such as HPF, MNF and Tank water level. This will help to improve performance of the scheme as well as the operations.

While designing a water supply distribution system, hydraulic simulations should be carried out using available modelling software like WaterGems, EPANET, etc. to decide on the appropriateness of a balancing reservoir as well as the identification of critical zones. Such options will help to reduce the cost of the distribution system by system optimization and to have a better pressure distribution throughout the system.

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APPENDIX A

Monthly consumption and connection data for domestic category

Table A-1 Monthly consumption for domestic category

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Connections
2000	1865	1871	1633	1680	1434	1375	1236	1443	1419	1762	1828	3343	20889	34
2001	969	1068	1101	869	942	855	880	744	773	744	774	704	10423	36
2002	706	726	750	616	326057	322487	339019	352306	360451	351026	323631	313092	2690867	15270
2003	336155	335335	339917	352642	352114	345942	350713.5	355485	364521	349929	363633	372853	4219240	16400
2004	379046	363146	363018	397802	361282	357188	366227	361201	361726	356427	349245	372768	4389076	17526
2005	399515	408113	367272	397377	346921	331742	350349	388254	372416	346614	336590	352721	4397884	18683
2006	371740	373865	369041	383824	381077	368697	365244	378033	374342	373903	377267	383756	4500789	19640
2007	414766	411066	421346	403786	385991	408592	396168	403955	408127	398348	394563	394078	4840786	20673
2008	304734	407536	376006	394667	403635	376748	387156	409883	410893	422133	420801	411502	4725694	21637
2009	436346	438953	433132	430495	440860	408096	392412	419207	410150	400059	408845	393543	5012098	22545
2010	411708	406506	421997	436676	418154	417526	408655	431676	440924	424037	436892	407426	5062177	23384
2011	431945	416312	434860	461325	433660	449306	450031	454774	457285	457855	448142	452346	5347841	24144
2012	460910	472978	460140	485699	504462	499750	439728	469262	460847	450306	465190	459020	5628292	25022
2013	468021	478998	465225	481369	492837	469068	452111	470482	487332	465296	478191	469359	5678289	25862
2014	513130	492435	478990	495708	482785	504979	497923	513872	485316	509496	479086	464756	5918476	26726

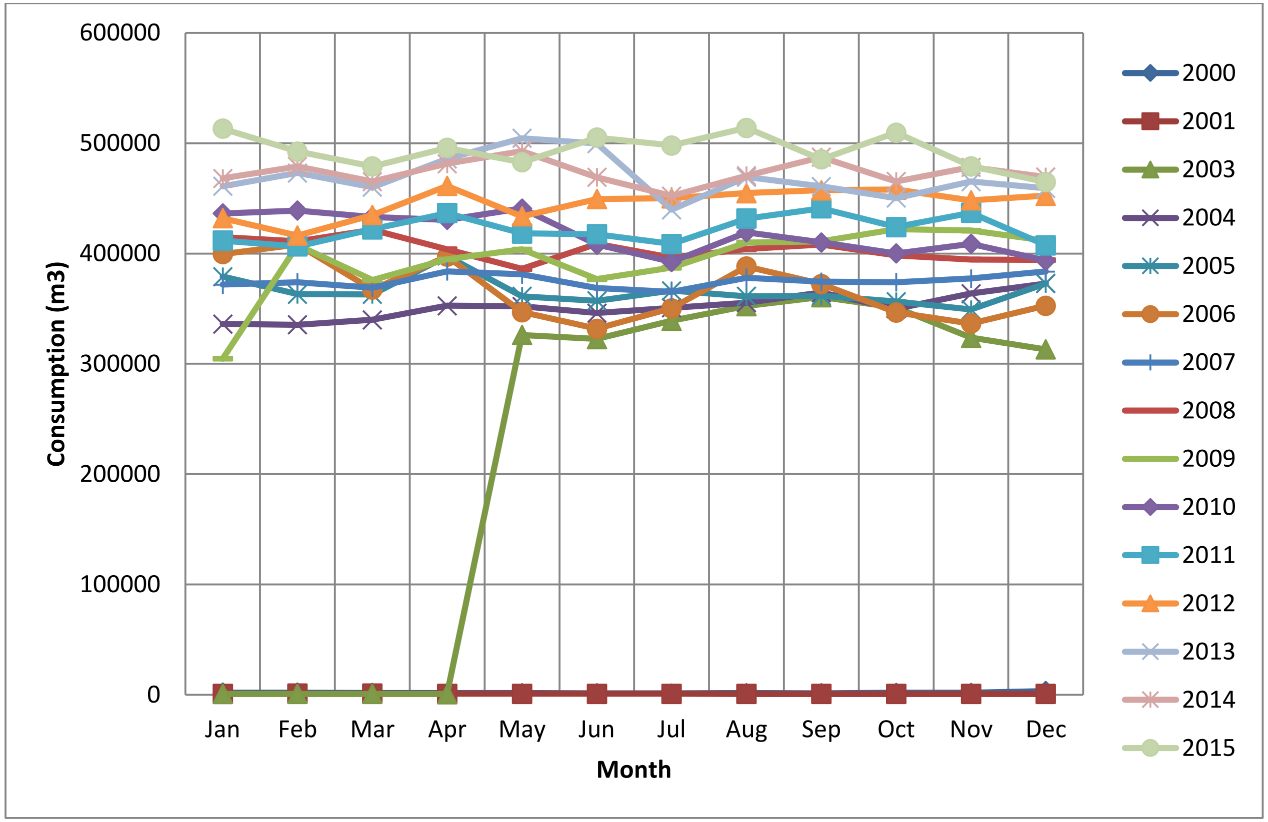


Figure A-1 Monthly Consumption for domestic category

Table A- 2 Monthly number of connection for domestic category

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	29	29	29	29	30	30	31	32	33	33	33	34
2001	32	33	35	35	35	35	35	35	35	36	36	36
2002	85	85	85	85	14634	14687	14748	14857	14973	15113	15207	15270
2003	15370	15426	15532	15567	15660	15843	15938.5	16034	16096	16201	16312	16400
2004	16513	16626	16655	16794	16869	16971	17074	17194	17255	17372	17449	17526
2005	17629	17632	17708	17796	17886	17938	17998	18050	18177	18404	18548	18683
2006	18714	18863	18919	19007	19112	19184	19288	19398	19452	19568	19641	19640
2007	19668	19783	19848	19930	19983	20111	20201	20303	20378	20523	20588	20673
2008	20722	20783	20835	20982	21071	21182	21257	21366	21438	21481	21557	21637
2009	21689	21722	21762	21806	21911	22041	22129	22211	22317	22386	22439	22545
2010	22611	22677	22751	22848	22937	22998	23060	23164	23201	23273	23315	23384
2011	23236	23312	23374	23418	23473	23534	23589	23656	23761	23866	24060	24144
2012	24180	24247	24313	24416	24496	24562	24653	24720	24802	24895	24962	25022
2013	25056	25130	25196	25280	25338	25385	25449	25542	25620	25688	25777	25862
2014	25864	25926	26006	26076	26140	26231	26299	26384	26493	26567	26656	26726

Table A-3 Monthly per connection consumption for domestic users

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	64.3	64.5	56.3	57.9	47.8	45.8	39.9	45.1	43.0	53.4	55.4	98.3
2001	30.3	32.4	31.5	24.8	26.9	24.4	25.1	21.3	22.1	20.7	21.5	19.6
2002					22.3	22.0	23.0	23.7	24.1	23.2	21.3	20.5
2003	21.9	21.7	21.9	22.7	22.5	21.8	22.0	22.2	22.6	21.6	22.3	22.7
2004	23.0	21.8	21.8	23.7	21.4	21.0	21.4	21.0	21.0	20.5	20.0	21.3
2005	22.7	23.1	20.7	22.3	19.4	18.5	19.5	21.5	20.5	18.8	18.1	18.9
2006	19.9	19.8	19.5	20.2	19.9	19.2	18.9	19.5	19.2	19.1	19.2	19.5
2007	21.1	20.8	21.2	20.3	19.3	20.3	19.6	19.9	20.0	19.4	19.2	19.1
2008	14.7	19.6	18.0	18.8	19.2	17.8	18.2	19.2	19.2	19.7	19.5	19.0
2009	20.1	20.2	19.9	19.7	20.1	18.5	17.7	18.9	18.4	17.9	18.2	17.5
2010	18.2	17.9	18.5	19.1	18.2	18.2	17.7	18.6	19.0	18.2	18.7	17.4
2011	18.6	17.9	18.6	19.7	18.5	19.1	19.1	19.2	19.2	19.2	18.6	18.7
2012	19.1	19.5	18.9	19.9	20.6	20.3	17.8	19.0	18.6	18.1	18.6	18.3
2013	18.7	19.1	18.5	19.0	19.5	18.5	17.8	18.4	19.0	18.1	18.6	18.1
2014	19.8	19.0	18.4	19.0	18.5	19.3	18.9	19.5	18.3	19.2	18.0	17.4

APPENDIX B

Monthly consumption and connection data for commercial category

Table B-1 Monthly consumption for commercial users

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Connections
2000	490	393	381	401	366	379	310	400	430	406	348	412	4716	14
2001	262	247	282	256	215	195	178	208	744	511	625	658	4381	11
2002	694	750	726	725	22863	22825	24524	25749	26906	26342	24849	24175	201128	779
2003	25813	25343	25033	24601	24982	24470	25166.5	25863	25119	24560	24842	28477	279241	868
2004	25588	24931	25441	25205	24932	24057	25439	25479	25640	24865	24535	28381	304493	992
2005	28371	29788	30285	30348	27433	28003	28426	31154	31129	28154	30574	29873	353538	1139
2006	32024	30232	30570	30440	31192	32145	31735	31878	32823	34042	34986	35849	387916	1273
2007	36451	36065	36536	34499	31955	34513	34766	34891	35702	39216	37796	38477	430867	1422
2008	38977	38003	36912	37288	38320	35443	36710	39081	39155	39312	40015	39997	459213	1542
2009	41022	37869	35715	35983	33977	35522	35084	35098	36034	36324	35950	36647	435225	1607
2010	37424	37057	39452	39852	37336	40037	38180	39526	41095	39869	43283	42672	475783	1703
2011	43720	41320	43233	42707	40301	43927	42759	44624	45415	45218	47547	45586	526357	1845
2012	47498	48274	46931	49470	48103	50951	44191	45573	47580	46751	51361	50281	576964	1989
2013	50917	49413	50369	51568	48494	49688	51382	51515	54283	51018	52103	53120	613870	2112
2014	56220	53713	52600	52818	49865	54787	53673	56514	54178	57299	54301	55940	651908	2219

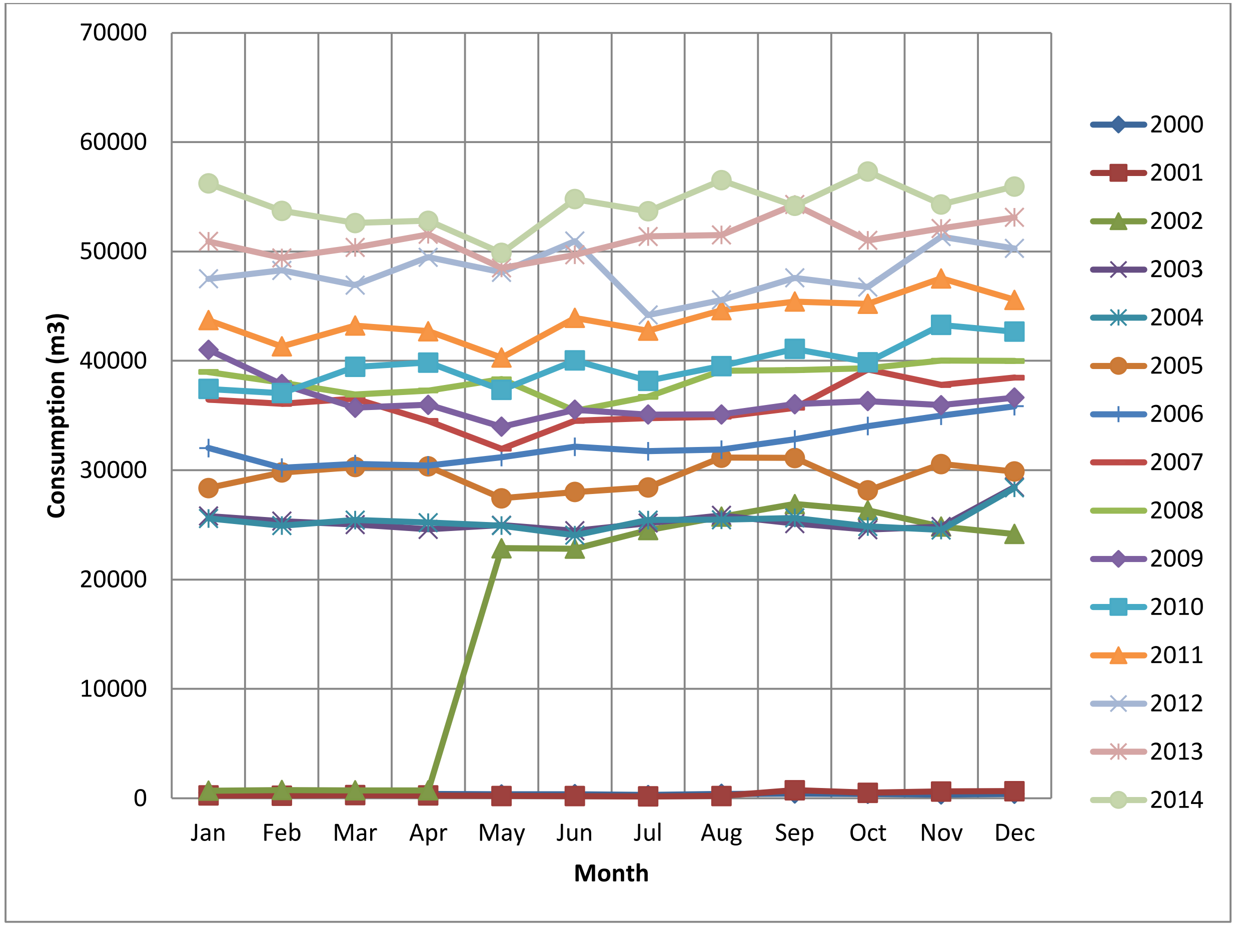


Figure B-1 Monthly Consumption for commercial category

Table B-2 Monthly connection details for commercial users

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	13	13	13	13	14	14	14	14	14	14	14	14
2001	10	10	10	10	10	10	10	10	10	11	11	11
2002					729	736	736	749	752	759	767	779
2003	780	796	798	803	814	818	824.5	831	834	835	839	868
2004	870	889	892	902	909	917	928	939	949	968	979	992
2005	1008	1041	1049	1055	1063	1061	1076	1081	1092	1109	1130	1139
2006	1157	1171	1183	1200	1212	1217	1224	1233	1235	1265	1270	1273
2007	1273	1287	1300	1310	1308	1320	1326	1349	1363	1383	1387	1422
2008	1443	1452	1471	1487	1492	1504	1506	1517	1524	1531	1538	1542
2009	1564	1550	1555	1558	1559	1569	1581	1577	1581	1584	1594	1607
2010	1593	1605	1610	1616	1625	1634	1642	1642	1671	1679	1685	1703
2011	1701	1714	1728	1740	1752	1752	1772	1784	1800	1817	1834	1845
2012	1858	1866	1889	1904	1909	1923	1936	1948	1865	1976	1983	1989
2013	2008	2019	2033	2042	2051	2063	2068	2078	2090	2104	2105	2112
2014	2098	2109	2122	2126	2143	2152	2158	2175	2185	2197	2214	2219

Table B-3 Monthly per connection consumption for commercial users

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	37.7	30.2	29.3	30.8	26.1	27.1	22.1	28.6	30.7	29.0	24.9	29.4
2001	26.2	24.7	28.2	25.6	21.5	19.5	17.8	20.8	74.4	46.5	56.8	59.8
2002					31.4	31.0	33.3	34.4	35.8	34.7	32.4	31.0
2003	33.1	31.8	31.4	30.6	30.7	29.9	30.5	31.1	30.1	29.4	29.6	32.8
2004	29.4	28.0	28.5	27.9	27.4	26.2	27.4	27.1	27.0	25.7	25.1	28.6
2005	28.1	28.6	28.9	28.8	25.8	26.4	26.4	28.8	28.5	25.4	27.1	26.2
2006	27.7	25.8	25.8	25.4	25.7	26.4	25.9	25.9	26.6	26.9	27.5	28.2
2007	28.6	28.0	28.1	26.3	24.4	26.1	26.2	25.9	26.2	28.4	27.3	27.1
2008	27.0	26.2	25.1	25.1	25.7	23.6	24.4	25.8	25.7	25.7	26.0	25.9
2009	26.2	24.4	23.0	23.1	21.8	22.6	22.2	22.3	22.8	22.9	22.6	22.8
2010	23.5	23.1	24.5	24.7	23.0	24.5	23.3	24.1	24.6	23.7	25.7	25.1
2011	25.7	24.1	25.0	24.5	23.0	25.1	24.1	25.0	25.2	24.9	25.9	24.7
2012	25.6	25.9	24.8	26.0	25.2	26.5	22.8	23.4	25.5	23.7	25.9	25.3
2013	25.4	24.5	24.8	25.3	23.6	24.1	24.8	24.8	26.0	24.2	24.8	25.2
2014	26.8	25.5	24.8	24.8	23.3	25.5	24.9	26.0	24.8	26.1	24.5	25.2

APPENDIX C

Daily Pumping Records

Table C-1 Daily inflow records for Maharagama Water Supply Scheme -2013

Daily Consumption Pattern of TEC-S Region
N33 Transmission Main

2013 - January

		Pump House			
Id	**Date**	**Maharagama**	**Kesbawa**	**Total**	**Flow Meter**
1	1-Jan	21172	15910	37082	40897
2	2-Jan	20905	16650	37555	41263
3	3-Jan	20232	15170	35402	37847
4	4-Jan	19120	13190	32310	36014
5	5-Jan	21715	16650	37252	40353
6	6-Jan	19047	14800	38365	35787
7	7-Jan	21247	16280	33847	40429
8	8-Jan	21077	15540	37527	40460
9	9-Jan	18575	12950	36617	36370
10	10-Jan	18575	12950	31525	36370
11	11-Jan	20244	15910	36154	38445
12	12-Jan	21150	16650	37800	41193
13	13-Jan	19957	15540	35497	40118
14	14-Jan	21330	15540	36870	38594
15	15-Jan	21347	15540	36887	35530
16	16-Jan	21160	16455	37615	41443
17	17-Jan	21344	16280	37624	39952
18	18-Jan	21540	17020	38560	40773
19	19-Jan	19362	14060	33422	35237
20	20-Jan	22465	17080	39545	42349
21	21-Jan	21525	15910	37435	41936
22	22-Jan	22093	16650	38743	41305
23	23-Jan	20985	15170	36155	40339
24	24-Jan	23437	16280	39717	39437
25	25-Jan	21347	15910	37257	41314
26	26-Jan	20595	16280	36875	40849
27	27-Jan	21900	16650	38550	41278

28	28-Jan	22455	16650	39105	41463
29	29-Jan	21717	17020	38737	42490
30	30-Jan	22827	17940	40767	42805
31	31-Jan	22280	16280	38560	42921
32	1-Feb	21907	16650	38557	41729
33	2-Feb	21807	17405	39212	40802
34	3-Feb	21269	16650	37919	42476
35	4-Feb	21807	16650	38457	42936
36	5-Feb	20972	17020	37992	42936
37	6-Feb	21715	15170	36885	42917
38	7-Feb	19047	16280	35327	39522
39	8-Feb	21247	15910	37157	42593
40	9-Feb	21077	15540	36617	37127
41	10-Feb	18575	16280	34855	36135
42	11-Feb	20244	15355	35599	42602
43	12-Feb	21150	15580	36730	30020
44	13-Feb	20805	15540	36345	41510
45	14-Feb	19962	15170	35132	39660
46	15-Feb	19452	15170	34622	39035
47	16-Feb	22184	16650	38834	37819
48	17-Feb	22465	16650	39115	42385
49	18-Feb	21530	16280	37810	43026
50	19-Feb	20325	15170	35495	42395
51	20-Feb	21132	16650	37782	40140
52	21-Feb	21629	15170	36799	40452
53	22-Feb	20786	16280	37066	40583
54	23-Feb	21170	16280	37450	40678
55	24-Feb	21155	16280	37435	41897
56	25-Feb	22655	16650	39305	40870
57	26-Feb	22877	16650	39527	41965
58	27-Feb	20992	16650	37642	42890
59	28-Feb	22834	17080	39914	40556
60	29-Feb	0	0	0	0

61	1-Mar	21760	16465	38225	43389
62	2-Mar	22579	17020	39599	41506
63	3-Mar	22650	16650	39300	42424
64	4-Mar	20327	15170	35497	43223
65	5-Mar	22707	17020	39727	40040
66	6-Mar	20450	16090	36540	43047
67	7-Mar	21904	18865	40769	40830
68	8-Mar	20040	19600	39640	41570
69	9-Mar	21079	20335	41414	38900
70	10-Mar	22650	20580	43230	42290
71	11-Mar	22280	20580	42860	48338
72	12-Mar	22652	21070	43722	42529
73	13-Mar	22637	21070	43707	44648
74	14-Mar	22004	20090	42094	42545
75	15-Mar	19055	18620	37675	42865
76	16-Mar	21900	20335	42235	38366
77	17-Mar	22365	20580	42945	38717
78	18-Mar	20250	21560	41810	43128
79	19-Mar	21629	19600	41229	41940
80	20-Mar	22087	21070	43157	43410
81	21-Mar	20904	19600	40504	42519
82	22-Mar	21530	19600	41130	41466
83	23-Mar	21804	19600	41404	39320
84	24-Mar	20682	18130	38812	42560
85	25-Mar	18045	19600	37645	43053
86	26-Mar	21529	19600	41129	34022
87	27-Mar	20967	18620	39587	42433
88	28-Mar	21344	20580	41924	42050
89	29-Mar	21150	19660	40810	41150
90	30-Mar	22644	20580	43224	40664
91	31-Mar	22932	21560	44492	43171
92	1-Apr	22350	20580	42930	41720
93	2-Apr	22650	20580	43230	42840

94	3-Apr	23104	21805	44909	48735
95	4-Apr	21900	20580	42480	44275
96	5-Apr	22167	20580	42747	41610
97	6-Apr	22656	21560	44216	43960
98	7-Apr	23775	22540	46315	43542
99	8-Apr	22817	20825	43642	44770
100	9-Apr	23492	22050	45542	43900
101	10-Apr	21525	20580	42105	44595
102	11-Apr	22197	18815	41012	42832
103	12-Apr	20212	20580	40792	40963
104	13-Apr	21447	22540	43987	41330
105	14-Apr	11187	16070	27257	43271
106	15-Apr	15585	16135	31720	43399
107	16-Apr	16622	14790	31412	39630
108	17-Apr	17670	17550	35220	33273
109	18-Apr	19087	19110	38197	37602
110	19-Apr	19512	19845	39357	38506
111	20-Apr	21723	19600	41323	40151
112	21-Apr	22092	20080	42172	40949
113	22-Apr	22340	20580	42920	40614
114	23-Apr	21720	20090	41810	41987
115	24-Apr	22080	21070	43150	42443
116	25-Apr	22815	20580	43395	42348
117	26-Apr	21618	20580	42198	42397
118	27-Apr	21452	21070	42522	41485
119	28-Apr	23190	20090	43280	43150
120	29-Apr	22531	21070	43601	42651
121	30-Apr	20974	20090	41064	43874
122	1-May	21934	20090	42024	42385
123	2-May	22204	20580	42784	34935
124	3-May	17840	15620	33460	45785
125	4-May	21099	20090	41189	34723
126	5-May	22923	21070	43993	46612
127	6-May	20390	16660	37050	41463

128	7-May	22239	22785	45024	37962
129	8-May	20737	21070	41807	43270
130	9-May	22903	21560	44463	39880
131	10-May	21555	20090	41645	40098
132	11-May	22391	18395	40786	39396
133	12-May	22587	19600	42187	42460
134	13-May	23062	17150	40212	38355
135	14-May	21187	20580	41767	42020
136	15-May	23290	19835	43125	43461
137	16-May	21910	20580	42490	42949
138	17-May	22582	20580	43162	42450
139	18-May	22435	20580	43015	40954
140	19-May	23054	20090	43144	42125
141	20-May	19914	15440	35354	37298
142	21-May	22178	15910	38088	40867
143	22-May	23053	20090	43143	40643
144	23-May	22195	19600	41795	41912
145	24-May	19914	17640	37554	35843
146	25-May	19056	17885	36941	35544
147	26-May	24843	19600	44443	40089
148	27-May	0	19600	19600	0
149	28-May	22993	19110	42103	42593
150	29-May	22614	20090	42704	41769
151	30-May	21931	18620	40551	39720
152	31-May	21633	16170	37803	39146
153	1-Jun	19195	17640	36835	30787
154	2-Jun	22305	19600	41905	39092
155	3-Jun	21064	20090	41154	41160
156	4-Jun	22602	18620	41222	40210
157	5-Jun	19893	17885	37778	40973
158	6-Jun	21894	20090	41984	38030
159	7-Jun	22332	19110	41442	41520
160	8-Jun	20276	18130	38406	36052
161	9-Jun	24623	20090	44713	44398

162	10-Jun	21390	18620	40010	40242
163	11-Jun	21593	18620	40213	40547
164	12-Jun	21426	16660	38086	38026
165	13-Jun	21171	19110	40281	38814
166	14-Jun	21894	20580	42474	42524
167	15-Jun	22171	19355	41526	40166
168	16-Jun	22162	19110	41272	41319
169	17-Jun	20902	16670	37572	38115
170	18-Jun	21227	17150	38377	37187
171	19-Jun	22520	17740	40260	41925
172	20-Jun	22391	18630	41021	40410
173	21-Jun	21415	18565	39980	37675
174	22-Jun	21347	19600	40947	39885
175	23-Jun	21457	18620	40077	39221
176	24-Jun	21436	19600	41036	38129
177	25-Jun	21430	18370	39800	39590
178	26-Jun	21969	16270	38239	39585
179	27-Jun	22785	20580	43365	41386
180	28-Jun	19613	10970	30583	38517
181	29-Jun	0	18620	18620	41304
182	30-Jun	12686	10665	23351	20450
183	1-Jul	24170	16355	40525	44215
184	2-Jul	22774	20090	42864	44215
185	3-Jul	21725	18865	40590	44855
186	4-Jul	22595	20090	42685	40854
187	5-Jul	22008	20090	42098	39970
188	6-Jul	20790	19355	40145	41565
189	7-Jul	22499	19110	41609	41511
190	8-Jul	22416	19600	42016	40139
191	9-Jul	20903	18355	39258	40175
192	10-Jul	20293	15780	36073	34430
193	11-Jul	22375	20535	42910	40193
194	12-Jul	22412	14970	37382	39030

195	13-Jul	23201	20440	43641	42818
196	14-Jul	23253	19955	43208	42405
197	15-Jul	22753	19020	41773	40747
198	16-Jul	23045	19455	42500	41420
199	17-Jul	22355	19835	42190	41220
200	18-Jul	20428	16460	36888	37174
201	19-Jul	22676	19905	42581	40861
202	20-Jul	21970	18390	40360	40745
203	21-Jul	22438	17680	40118	41325
204	22-Jul	19506	14430	33936	36317
205	23-Jul	20511	18065	38576	36855
206	24-Jul	21564	19720	41284	39613
207	25-Jul	22244	17995	40239	40587
208	26-Jul	20475	17225	37700	375233
209	27-Jul	22665	18700	41365	40028
210	28-Jul	23399	18740	42139	42011
211	29-Jul	21518	18310	39828	40656
212	30-Jul	23331	18000	41331	42015
213	31-Jul	22645	19550	42195	41241
214	1-Aug	22512	18980	41492	42564
215	2-Aug	20700	17975	38675	37975
216	3-Aug	22629	19700	42329	41730
217	4-Aug	18164	16930	35094	34594
218	5-Aug	21560	19945	41505	41021
219	6-Aug	22494	18905	41399	42310
220	7-Aug	22734	19795	42529	41210
221	8-Aug	22385	18260	40645	41811
222	9-Aug	21981	19360	41341	40679
223	10-Aug	21117	17260	38377	40515
224	11-Aug	22100	16095	38195	41885
225	12-Aug	22422	16650	39072	39416
226	13-Aug	23619	17265	40884	42314
227	14-Aug	22768	16650	39418	40920

228	15-Aug	22521	16640	39161	40535
229	16-Aug	22429	16520	38949	41651
230	17-Aug	21851	17200	39051	40794
231	18-Aug	22129	18975	41104	40395
232	19-Aug	21690	19090	40780	40666
233	20-Aug	21812	20650	42462	40589
234	21-Aug	22437	19208	41645	41130
235	22-Aug	22460	20630	43090	40335
236	23-Aug	23330	19045	42375	41917
237	24-Aug	22762	19660	42422	39983
238	25-Aug	22056	20040	42096	41448
239	26-Aug	24026	20160	44186	40819
240	27-Aug	23110	19860	42970	43363
241	28-Aug	22202	18910	41112	41571
242	29-Aug	22844	20090	42934	43449
243	30-Aug	22053	21070	43123	40722
244	31-Aug	23222	20580	43802	43613
245	1-Sep	21823	21560	43383	41360
246	2-Sep	18929	18900	37829	31104
247	3-Sep	24433	16070	40503	40371
248	4-Sep	21462	19845	41307	42041
249	5-Sep	21315	16140	37455	37320
250	6-Sep	10853	18530	29383	38286
251	7-Sep	21588	18620	40208	39179
252	8-Sep	23296	20580	43876	42900
253	9-Sep	22828	20580	43408	42743
254	10-Sep	22756	20580	43336	41133
255	11-Sep	22756	20580	43336	40655
256	12-Sep	22569	19110	41679	39610
257	13-Sep	22298	19110	41408	39677
258	14-Sep	22232	20250	42482	43853
259	15-Sep	24283	18160	42443	42061
260	16-Sep	22697	19110	41807	40590

261	17-Sep	21221	16940	38161	41049
262	18-Sep	21032	15785	36817	37162
263	19-Sep	22769	21290	44059	40558
264	20-Sep	21840	17680	39520	40465
265	21-Sep	22104	20140	42244	39705
266	22-Sep	15953	15680	31633	25595
267	23-Sep	22517	18745	41262	41656
268	24-Sep	23921	18930	42851	43796
269	25-Sep	23331	22050	45381	41239
270	26-Sep	23059	21560	44619	42731
271	27-Sep	23331	20825	44156	39994
272	28-Sep	21964	21330	43294	40826
273	29-Sep	23647	20870	44517	41979
274	30-Sep	21960	17960	39920	42655
275	1-Oct	22850	17940	40790	42700
276	2-Oct	23183	18215	41398	40990
277	3-Oct	23705	20140	43845	41470
278	4-Oct	22344	19770	42114	42245
279	5-Oct	22145	19140	41285	40478
280	6-Oct	23096	19770	42866	41505
281	7-Oct	23135	18420	41555	43497
282	8-Oct	22049	20290	42339	36724
283	9-Oct	23135	19205	42340	43457
284	10-Oct	22045	18130	40175	39996
285	11-Oct	21716	19630	41346	41268
286	12-Oct	22953	19520	42473	41912
287	13-Oct	22221	18383	40604	40151
288	14-Oct	23875	16710	40585	42537
289	15-Oct	23005	16960	39965	40655
290	16-Oct	23501	19440	42941	44280
291	17-Oct	20870	19270	40140	39135
292	18-Oct	21744	19600	41344	39260
293	19-Oct	19741	13910	33651	35385

294	20-Oct	25074	16280	41354	41249
295	21-Oct	22172	19570	41742	40164
296	22-Oct	23748	16280	40028	43092
297	23-Oct	23645	17020	40665	42099
298	24-Oct	23315	17895	41210	42579
299	25-Oct	23272	21560	44832	40619
300	26-Oct	22910	20420	43330	41868
301	27-Oct	23270	20220	43490	42395
302	28-Oct	21662	17605	39267	39810
303	29-Oct	23350	19060	42410	42189
304	30-Oct	22719	19645	42364	41264
305	31-Oct	22580	17430	40010	40301
306	1-Nov	22779	18790	41569	41581
307	2-Nov	21586	17810	39396	39255
308	3-Nov	23308	18555	41863	41491
309	4-Nov	21448	18180	39628	40398
310	5-Nov	23340	18770	42110	41711
311	6-Nov	22755	20075	42830	42065
312	7-Nov	22403	18210	40613	40740
313	8-Nov	21763	16880	38643	41430
314	9-Nov	22661	16650	39311	39025
315	10-Nov	22477	16090	38567	41182
316	11-Nov	23460	15405	38865	40138
317	12-Nov	22691	17205	39896	37692
318	13-Nov	20992	16095	37087	39577
319	14-Nov	23515	17740	41255	40783
320	15-Nov	23527	16315	39842	41926
321	16-Nov	23345	16910	40255	41139
322	17-Nov	22959	17760	40719	38246
323	18-Nov	22614	18060	40674	41499
324	19-Nov	23590	15910	39500	41995
325	20-Nov	23563	15910	39473	41445
326	21-Nov	23394	17020	40414	43399
327	22-Nov	23797	16470	40267	40711

328	23-Nov	22922	15690	38612	39349
329	24-Nov	22753	16650	39403	40825
330	25-Nov	21687	16430	38117	41300
331	26-Nov	23053	16650	39703	41535
332	27-Nov	23337	17020	40357	41348
333	28-Nov	21599	17770	39369	42344
334	29-Nov	23374	11580	34954	41273
335	30-Nov	22395	17000	39395	40965
336	1-Dec	22739	16430	39169	40875
337	2-Dec	22445	15540	37985	41226
338	3-Dec	23358	17535	40893	40739
339	4-Dec	22927	17180	40107	40895
340	5-Dec	22361	17785	40146	43135
341	6-Dec	22177	18550	40727	42233
342	7-Dec	22704	17815	40519	40227
343	8-Dec	23019	16230	39249	41141
344	9-Dec	23390	17590	40980	41517
345	10-Dec	23491	16050	39541	42162
346	11-Dec	23764	15010	38774	41785
347	12-Dec	23851	16400	40251	40915
348	13-Dec	22549	18650	41199	43305
349	14-Dec	22350	18900	41250	41705
350	15-Dec	21074	19600	40674	40611
351	16-Dec	21556	19480	41036	40176
352	17-Dec	22691	18400	41091	41209
353	18-Dec	23000	20020	43020	41776
354	19-Dec	23095	17695	40790	41704
355	20-Dec	22264	17695	39959	41920
356	21-Dec	23563	20720	44283	41330
357	22-Dec	23037	18790	41827	41154
358	23-Dec	23844	18700	42544	40272
359	24-Dec	21690	21690	43380	42100
360	25-Dec	23580	23580	47160	41074
361	26-Dec	22919	22919	45838	41035
362	27-Dec	22590	18785	41375	41250

363	28-Dec	22922	18070	40992	41870
364	29-Dec	22615	19200	41815	40871
365	30-Dec	23917	18990	42907	41510
366	31-Dec	23941	16045	39986	46029

Table C-2 Daily inflow records for Maharagama Water Supply Scheme -2014

Daily Consumption Pattern of TEC-S Region N33 Transmission Main

2014 - January

		Pump House			
Id	**Date**	**Maharagama**	**Kesbawa**	**Total**	**Flow Meter**
1	1-Jan	23941	21370	45311	46026
2	2-Jan	23440	19340	42780	45146
3	3-Jan	23039	16710	39749	43275
4	4-Jan	23324	16880	40204	42980
5	5-Jan	22090	16170	21936	37270
6	6-Jan	23551	18115	38260	44279
7	7-Jan	23522	17485	41666	43260
8	8-Jan	23445	17550	41007	42965
9	9-Jan	22316	16875	40995	43336
10	10-Jan	22316	16875	39191	43336
11	11-Jan	22961	18410	41371	42544
12	12-Jan	22557	17965	40522	40546
13	13-Jan	22478	16650	39128	43541
14	14-Jan	22488	18300	40788	42283
15	15-Jan	22653	20090	42743	39205
16	16-Jan	21720	15910	37630	40278
17	17-Jan	23130	16900	40030	42327
18	18-Jan	23596	17810	41406	41905
19	19-Jan	23605	19745	43350	42235
20	20-Jan	22999	15545	38544	43445

21	21-Jan	23000	19861	42861	39645
22	22-Jan	23106	16550	39656	39219
23	23-Jan	22807	16180	38987	42101
24	24-Jan	21455	16280	37735	46670
25	25-Jan	22622	18190	40812	42080
26	26-Jan	23011	16625	39636	41655
27	27-Jan	23836	17360	41196	44280
28	28-Jan	22208	16050	38258	42955
29	29-Jan	22317	16620	38937	44321
30	30-Jan	23289	17790	41079	41620
31	31-Jan	23100	19420	42520	43375
32	1-Feb	23197	1660	24857	41635
33	2-Feb	23235	15170	38405	42166
34	3-Feb	21098	14787	35885	42394
35	4-Feb	23458	15620	39078	42880
36	5-Feb	23200	15650	38850	42965
37	6-Feb	22051	15880	37931	41196
38	7-Feb	22744	15480	38224	42862
39	8-Feb	29844	15670	45514	42609
40	9-Feb	23384	15670	39054	42091
41	10-Feb	21461	16050	37511	43795
42	11-Feb	22212	15520	37732	42880
43	12-Feb	22468	16130	38598	42610
44	13-Feb	21213	16280	37493	42638
45	14-Feb	22343	18270	40613	42712
46	15-Feb	22220	16380	38600	42120
47	16-Feb	22790	18050	40840	41920
48	17-Feb	22444	15690	38134	42807
49	18-Feb	22556	16410	38966	42488
50	19-Feb	22141	15480	37621	42670
51	20-Feb	21771	15935	37706	42811
52	21-Feb	21864	17230	39094	44429
53	22-Feb	22868	20300	43168	42242

54	23-Feb	22680	17710	40390	42653
55	24-Feb	22545	18080	40625	43956
56	25-Feb	24152	20740	44892	44044
57	26-Feb	22526	18910	41436	43875
58	27-Feb	22921	19180	42101	43191
59	28-Feb	23043	18600	41643	43474
60	29-Feb	0	0	0	0
61	1-Mar	23043	16810	39853	43473
62	2-Mar	22691	16230	38921	43351
63	3-Mar	22669	16980	39649	41869
64	4-Mar	22472	14150	36622	42415
65	5-Mar	22370	13280	35650	42710
66	6-Mar	23260	15490	38750	43270
67	7-Mar	23597	15970	39567	43945
68	8-Mar	22688	18020	40708	43515
69	9-Mar	22691	17860	40551	42456
70	10-Mar	23551	15555	39106	42545
71	11-Mar	22444	14855	37299	42807
72	12-Mar	22733	15145	37878	41902
73	13-Mar	22700	14150	36850	41995
74	14-Mar	22775	13580	36355	40095
75	15-Mar	21587	14530	36117	41816
76	16-Mar	22710	15270	37980	42644
77	17-Mar	23039	14350	37389	42475
78	18-Mar	22244	15690	37934	41225
79	19-Mar	21546	18590	40136	42390
80	20-Mar	22529	17590	40119	44205
81	21-Mar	22596	19725	42321	42784
82	22-Mar	22800	18540	41340	42301
83	23-Mar	22624	17950	40574	42521
84	24-Mar	22911	15880	38791	42169
85	25-Mar	22317	14930	37247	42792
86	26-Mar	22760	18950	41710	43688

87	27-Mar	22434	14815	37249	43215
88	28-Mar	22016	15960	37976	42030
89	29-Mar	23146	18550	41696	42660
90	30-Mar	22342	17855	40197	43230
91	31-Mar	22502	17920	40422	43065
92	1-Apr	21330	18330	39660	41718
93	2-Apr	22340	15195	37535	42700
94	3-Apr	21885	15540	37425	42371
95	4-Apr	21516	15345	36861	41164
96	5-Apr	18510	17380	35890	39977
97	6-Apr	22554	19140	41694	42135
98	7-Apr	22501	19160	41661	43840
99	8-Apr	22433	18670	41103	43570
100	9-Apr	21866	20195	42061	44113
101	10-Apr	23364	18195	41559	42622
102	11-Apr	22083	18680	40763	43441
103	12-Apr	22178	18790	40968	43329
104	13-Apr	22110	20260	42370	42885
105	14-Apr	22362	17420	39782	43130
106	15-Apr	17684	16700	34384	37358
107	16-Apr	17806	16640	34446	35771
108	17-Apr	17228	18640	35868	35894
109	18-Apr	18702	16660	35362	39462
110	19-Apr	19988	19250	39238	38300
111	20-Apr	21618	20560	42178	40045
112	21-Apr	22743	17550	40293	42800
113	22-Apr	22978	17640	40618	43840
114	23-Apr	22073	19360	41433	40505
115	24-Apr	22937	19640	42577	43161
116	25-Apr	22750	18360	41110	43464
117	26-Apr	23147	15280	38427	42535
118	27-Apr	23934	17015	40949	42180
119	28-Apr	22094	18825	40919	42185

120	29-Apr	21282	17690	38972	35901
121	30-Apr	22508	19240	41748	32879
122	1-May	22991	19860	42851	42333
123	2-May	22840	18000	40840	41462
124	3-May	20758	18620	39378	42023
125	4-May	22330	18790	41120	40882
126	5-May	22932	19030	41962	41532
127	6-May	21021	20090	41111	42080
128	7-May	23545	18500	42045	42328
129	8-May	22408	18560	40968	43008
130	9-May	23522	19495	43017	42062
131	10-May	21880	17750	39630	42808
132	11-May	22760	14460	37220	39372
133	12-May	24024	16155	40179	41795
134	13-May	21670	16530	38200	41662
135	14-May	21642	16915	38557	41770
136	15-May	21246	18450	39696	43406
137	16-May	22921	17930	40851	43030
138	17-May	21793	17930	39723	42854
139	18-May	22579	18500	41079	42794
140	19-May	23064	16540	39604	42057
141	20-May	22335	17490	39825	41519
142	21-May	21885	18310	40195	42038
143	22-May	21072	20210	41282	43330
144	23-May	22553	18240	40793	42209
145	24-May	21980	17190	39170	41901
146	25-May	22550	15780	38330	41530
147	26-May	22974	15080	38054	42496
148	27-May	22619	16050	38669	42880
149	28-May	23502	20100	43602	46674
150	29-May	23943	19600	43543	46515
151	30-May	24290	21560	45850	45290
152	31-May	23285	19600	42885	44344
153	1-Jun	24351	20090	44441	45075
154	2-Jun	23227	17640	40867	42474

155	3-Jun	22423	21070	43493	41406
156	4-Jun	22576	20090	42666	39826
157	5-Jun	23643	19110	42753	44403
158	6-Jun	24161	20090	44251	45737
159	7-Jun	23382	20580	43962	42935
160	8-Jun	24244	19870	44114	44744
161	9-Jun	23750	19270	43020	44859
162	10-Jun	24005	20600	44605	45307
163	11-Jun	24080	20580	44660	44305
164	12-Jun	21876	22540	44416	43652
165	13-Jun	22773	19110	41883	44608
166	14-Jun	22496	20900	43396	42180
167	15-Jun	22984	19600	42584	43785
168	16-Jun	23560	19760	43320	43545
169	17-Jun	24340	16905	41245	45416
170	18-Jun	19850	19580	39430	34850
171	19-Jun	24379	17810	42189	44999
172	20-Jun	24200	17450	41650	45010
173	21-Jun	24643	13275	37918	42772
174	22-Jun	24123	15380	39503	42320
175	23-Jun	23710	17510	41220	42836
176	24-Jun	23200	19060	42260	43935
177	25-Jun	22537	19600	42137	46146
178	26-Jun	24313	19600	43913	47680
179	27-Jun	24385	21560	45945	46109
180	28-Jun	24680	21070	45750	47330
181	29-Jun	28274	20580	48854	45440
182	30-Jun	24106	21070	45176	47621
183	1-Jul	24274	22540	46814	44890
184	2-Jul	24236	19845	44081	47282
185	3-Jul	24237	22640	46877	46718
186	4-Jul	23604	19270	42874	43840
187	5-Jul	23743	15910	39653	44635

188	6-Jul	23972	19640	43612	45750
189	7-Jul	24819	19990	44809	46215
190	8-Jul	24960	20970	45930	46405
191	9-Jul	23890	20490	44380	45440
192	10-Jul	24008	19730	43738	47860
193	11-Jul	24008	20010	44018	47800
194	12-Jul	23149	20100	43249	44480
195	13-Jul	22844	20730	43574	44066
196	14-Jul	24174	20600	44774	46296
197	15-Jul	24360	22835	47195	43677
198	16-Jul	24234	21245	45479	42797
199	17-Jul	24028	20720	44748	45478
200	18-Jul	24320	20360	44680	46222
201	19-Jul	23617	20620	44237	45267
202	20-Jul	23425	20350	43775	46650
203	21-Jul	24170	20730	44900	45900
204	22-Jul	24918	21070	45988	43608
205	23-Jul	25287	21100	46387	50730
206	24-Jul	25066	20308	45374	47236
207	25-Jul	25020	20570	45590	46244
208	26-Jul	24500	19520	44020	46555
209	27-Jul	24246	20120	44366	44397
210	28-Jul	23409	20090	43499	46246
211	29-Jul	22654	21830	44484	43437
212	30-Jul	24120	20120	44240	46450
213	31-Jul	24147	20850	44997	45011
214	1-Aug	23742	20580	44322	45469
215	2-Aug	20200	12445	32645	38335
216	3-Aug	12876	8820	21696	28803
217	4-Aug	11266	18390	29656	16349
218	5-Aug	19242	18620	37862	22984
219	6-Aug	22787	14750	37537	38312
220	7-Aug	23360	19045	42405	4205

221	8-Aug	23565	15346	38911	39922
222	9-Aug	22085	20175	42260	44466
223	10-Aug	22165	20090	42255	39983
224	11-Aug	23226	21070	44296	49163
225	12-Aug	21282	21070	42352	42283
226	13-Aug	22197	18570	40767	46878
227	14-Aug	27418	17200	44618	43167
228	15-Aug	22680	17945	40625	44640
229	16-Aug	22200	17020	39220	44276
230	17-Aug	22125	16650	38775	44100
231	18-Aug	20650	16095	36745	41236
232	19-Aug	21500	17575	39075	43154
233	20-Aug	21625	17760	39385	45315
234	21-Aug	22550	17760	40310	46147
235	22-Aug	20775	17020	37795	34198
236	23-Aug	19675	17020	36695	38850
237	24-Aug	21625	17575	39200	46060
238	25-Aug	22025	17760	39785	47816
239	26-Aug	22550	17760	40310	40206
240	27-Aug	22900	17760	40660	46866
241	28-Aug	21875	18680	40555	43827
242	29-Aug	22550	23030	45580	46637
243	30-Aug	22550	21560	44110	47131
244	31-Aug	22200	22050	44250	46029
245	1-Sep	22550	22050	44600	47303
246	2-Sep	22550	23030	45580	47894
247	3-Sep	22650	21070	43720	46202
248	4-Sep	21150	22540	43690	46961
249	5-Sep	22200	21315	43515	46570
250	6-Sep	21625	21560	43185	44101
251	7-Sep	21935	17620	39555	47453
252	8-Sep	20100	16465	36565	37095
253	9-Sep	19050	21805	40855	31830

254	10-Sep	22025	20580	42605	48790
255	11-Sep	22025	20580	42605	44411
256	12-Sep	22725	20580	43305	47707
257	13-Sep	21150	22540	43690	45425
258	14-Sep	22200	21560	43760	47460
259	15-Sep	22200	22540	44740	49934
260	16-Sep	22200	21315	43515	45603
261	17-Sep	23250	21560	44810	48770
262	18-Sep	21850	23520	45370	47998
263	19-Sep	23900	21070	44970	47935
264	20-Sep	22900	22540	45440	44669
265	21-Sep	22935	22540	45475	50071
266	22-Sep	22900	22685	45585	49908
267	23-Sep	22900	21560	44460	38013
268	24-Sep	23950	21560	45510	56114
269	25-Sep	22900	18130	41030	50273
270	26-Sep	22375	14430	36805	44787
271	27-Sep	21675	20350	42025	43972
272	28-Sep	22110	17760	39870	45878
273	29-Sep	23625	17760	41385	48605
274	30-Sep	22900	17760	40660	49942
275	1-Oct	23375	17760	41135	46118
276	2-Oct	22900	17760	40660	49328
277	3-Oct	22550	17760	40310	44792
278	4-Oct	21856	17760	39616	47200
279	5-Oct	22250	15975	38225	45855
280	6-Oct	22250	18390	40640	48709
281	7-Oct	20700	18240	38940	44565
282	8-Oct	19825	18200	38025	43296
283	9-Oct	22200	19680	41880	46495
284	10-Oct	20925	18720	39645	46700
285	11-Oct	22566	19680	42246	44002
286	12-Oct	23910	19680	43590	49758

287	13-Oct	23416	19680	43096	48068
288	14-Oct	24952	19680	44632	45732
289	15-Oct	24960	19680	44640	50550
290	16-Oct	24270	19680	43950	49773
291	17-Oct	23611	18720	42331	47187
292	18-Oct	23120	19680	42800	45592
293	19-Oct	22814	18720	41534	44362
294	20-Oct	22709	15910	38619	48545
295	21-Oct	22955	16280	39235	46829
296	22-Oct	23967	18935	42902	45406
297	23-Oct	23822	20580	44402	48926
298	24-Oct	23247	18730	41977	42584
299	25-Oct	22658	19600	42258	43947
300	26-Oct	22716	20580	43296	45723
301	27-Oct	23075	19110	42185	48123
302	28-Oct	22622	21560	44182	43873
303	29-Oct	23225	19600	42825	44300
304	30-Oct	23298	17640	40938	44545
305	31-Oct	22030	19353	41383	40438
306	1-Nov	22437	19880	42317	42356
307	2-Nov	22980	18130	41110	44160
308	3-Nov	23069	20090	43159	45550
309	4-Nov	20720	17150	37870	40770
310	5-Nov	22062	22080	44142	40800
311	6-Nov	23487	19110	42597	45794
312	7-Nov	23393	21560	44953	44589
313	8-Nov	23205	19600	42805	43545
314	9-Nov	23203	20090	43293	42842
315	10-Nov	24237	20090	44327	46774
316	11-Nov	23994	21070	45064	43674
317	12-Nov	23900	20090	43990	46325
318	13-Nov	23624	19775	43399	43170
319	14-Nov	23453	17640	41093	46045
320	15-Nov	22515	18830	41345	40803

321	16-Nov	23491	17630	41121	43984
322	17-Nov	22397	18405	40802	43176
323	18-Nov	22531	20580	43111	42752
324	19-Nov	23330	18620	41950	42650
325	20-Nov	22575	20580	43155	43473
326	21-Nov	23905	18620	42525	44562
327	22-Nov	22883	18730	41613	42860
328	23-Nov	23300	18620	41920	41301
329	24-Nov	23350	19110	42460	45059
330	25-Nov	23466	19090	42556	43905
331	26-Nov	22630	17760	40390	41210
332	27-Nov	22383	18310	40693	39829
333	28-Nov	23224	18280	41504	43741
334	29-Nov	22156	18620	40776	41511
335	30-Nov	23518	18620	42138	42689
336	1-Dec	22733	19130	41863	41760
337	2-Dec	23130	21070	44200	43425
338	3-Dec	24027	20090	44117	45365
339	4-Dec	24457	19600	44057	45940
340	5-Dec	23463	19600	43063	42069
341	6-Dec	23630	19110	42740	43596
342	7-Dec	23493	18840	42333	44415
343	8-Dec	23373	17880	41253	43495
344	9-Dec	22840	21070	43910	41423
345	10-Dec	24133	20468	44601	45611
346	11-Dec	22954	19120	42074	42516
347	12-Dec	23745	18620	42365	43551
348	13-Dec	23666	19845	43511	43576
349	14-Dec	23770	20425	44195	44781
350	15-Dec	23748	19600	43348	44784
351	16-Dec	24616	20580	45196	44967
352	17-Dec	23770	19600	43370	45986
353	18-Dec	23303	21070	44373	41620
354	19-Dec	24275	20580	44855	45650
355	20-Dec	23512	18120	41632	45056

356	21-Dec	21924	19600	41524	45608
357	22-Dec	23746	19110	42856	45661
358	23-Dec	22449	19110	41559	41378
359	24-Dec	22193	18220	40413	42892
360	25-Dec	21870	17760	39630	41200
361	26-Dec	21175	19845	41020	40338
362	27-Dec	26569	19100	45669	38873
363	28-Dec	22542	18620	41162	44564
364	29-Dec	22130	20090	42220	41880
365	30-Dec	23912	17900	41812	42773
366	31-Dec	21701	8575	30276	42273

APPENDIX D

Hourly flow obtained through water balance model for study period

Table D-1 Hourly flow for the period of 2013 December 22 to 28

Time	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1.00		587.369	366.6087	369.9528	361.0574	305.1	528.1713
2.00		409.3242	325.9263	320.7551	301.7322	284.999	350.906
3.00		331.2053	308.5264	303.1895	323.2749	293.1275	324.4263
4.00		318.8735	332.7205	387.3765	398.6743	309.1098	379.9344
5.00		354.2632	391.8801	501.3085	780.2373	399.3104	338.7571
6.00	773.2287	1078.95	281.5152	876.8959	884.1921	826.8242	615.0849
7.00	1100.102	1282.676	514.8212	938.3511	1212.801	1380.993	1192.085
8.00	1075.999	1582.703	949.2573	1321.696	1162.092	1474.863	1111.621
9.00	1499.192	1369.965	1400.179	1200.033	1050.259	1182.617	1300.392
10.00	1247.173	1168.274	1238.028	1020.626	1094.61	1135.315	1202.979
11.00	1142.266	1126.951	1037.902	989.8521	1074.779	1069.189	1133.95
12.00	1119.75	917.8224	781.5591	962.3126	873.0412	1027.164	1068.246
13.00	1115.917	850.6941	603.1341	881.2005	948.3541	1079.391	1094.257
14.00	1109.667	913.6534	894.879	853.9851	1000.804	1068.11	1120.48
15.00	1088.686	785.3776	874.9401	1032.175	750.2997	1150.807	1106.916
16.00	1114.268	885.9644	706.4837	861.4271	827.9086	855.9827	1029.953
17.00	1125.525	866.9131	781.657	826.4546	880.4934	977.462	1148.386
18.00	1088.982	912.3242	904.2099	925.4254	922.434	1115.287	1094.392
19.00	1102.41	797.1642	923.0178	955.9932	1103.208	983.5966	1138.887
20.00	1113.179	706.1992	738.9126	492.4481	924.439	880.9693	852.8993
21.00	1053.733	716.4944	717.4608	808.3608	708.7429	750.0975	892.0066
22.00	943.9843	746.6799	640.653	1255.069	750.2358	792.7988	791.1428
23.00	842.0498	853.9568	670.8542	774.9659	669.9626	733.1087	644.9345
24.00	454.8709	473.8252	463.3125	1443.859	470.228	514.9721	581.6214

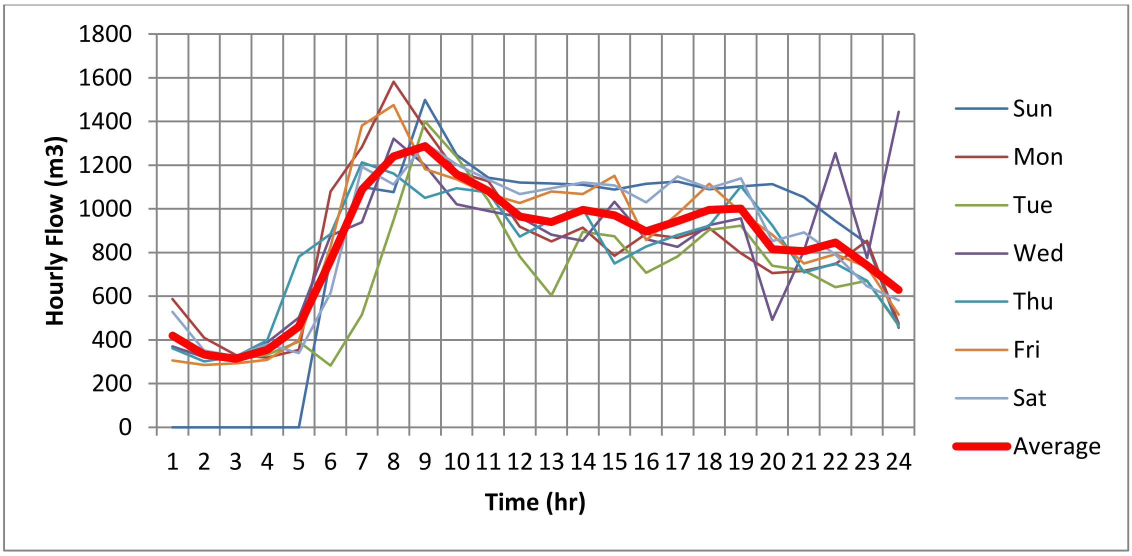


Table D-1 Hourly flow for the period of 2014 April 13 to 19

Time	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1.00	649.6545	687.75	545.5889	460.6824	471.9376	458.5991	860.687
2.00	407.9578	474.7465	430.217	402.2134	389.1881	337.031	374.3181
3.00	352.3349	352.2012	399.0696	412.1062	364.8328	330.375	356.312
4.00	529.0732	403.6966	406.5315	365.4613	420.5757	275.6164	601.8212
5.00	833.6636	1014.351	430.4142	585.6738	507.8893	800.628	661.4878
6.00	852.9553	1177.615	1028.631	1216.702	748.404	1096.821	1042.363
7.00	1121.677	1618.394	1538.404	1543.536	863.4161	1187.646	1097.598
8.00	1348.402	1333.153	1518.606	1498.735	1250.198	1378.203	1478.27
9.00	1472.532	1156.503	1201.045	1168.622	1340.482	1335.024	1116.818
10.00	1381.232	1139.119	1199.255	1149.295	1357.871	1198.407	1371.189
11.00	989.9362	934.2491	959.3113	879.6646	1112.205	981.7771	1063.92
12.00	1145.348	1044.907	1073.2	963.3329	1265.736	1090.709	1162.332
13.00	1158.516	1057.296	1077.566	921.3234	1259.376	1079.942	1145.955
14.00	1157.915	1024.716	1094.428	980.4146	1207.85	1029.797	1160.933
15.00	1121.564	1031.365	1082.192	1099.383	1104.873	1240.913	1305.778
16.00	1095.139	1017.766	1045.459	952.6209	1064.504	1020.537	1082.479
17.00	1147.279	1091.224	1027.999	1061.724	1113.204	1053.085	1152.173
18.00	1163.515	1213.187	1123.957	1250.967	1130.14	1168.085	1174.653
19.00	1128.215	1403.104	1250.145	943.3965	955.1179	1254.309	1131.778
20.00	1121.583	1240.151	1189.42	1073.727	827.2446	1104.228	1063.983
21.00	1059.072	1170.04	1158.24	1052.442	956.4934	985.221	1018.507
22.00	1022.158	1079.125	1113.707	1062.197	1041.336	1088.632	988.8019
23.00	688.2506	664.7999	762.0767	760.4994	640.0483	996.498	642.9401
24.00	637.9235	554.8117	692.1544	860.6092	564.4024	1000.831	1498.859

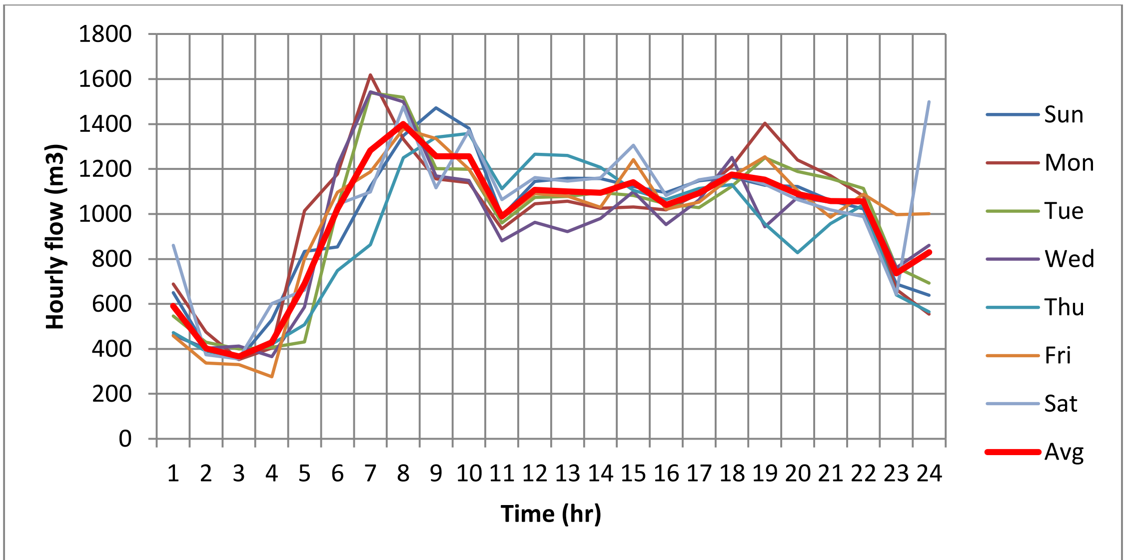


Table D-1 Hourly flow for the period of 2014 June 22 to 28

Time	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1.00	648.5701	674.6895	732.9823	805.4543	289.5136	375.5254	607.5584
2.00	536.0864	332.6768	521.9773	720.2348	502.0935	532.5895	506.7977
3.00	339.0977	224.1935	604.77	641.436	496.8979	390.5101	443.1006
4.00	974.5976	784.2881	972.407	550.6205	790.7825	440.314	284.2805
5.00	613.5904	824.1586	935.3196	1032.047	858.8094	680.4237	526.2272
6.00	924.502	1503.063	1294.999	1302.078	1192.933	1417.319	388.8065
7.00	1390.387	1268.182	1707.411	1399.044	1709.395	1679.782	1330.984
8.00	1624.173	1112.232	1133.798	1137.535	1367.151	1394.281	1607.733
9.00	1327.181	1103.899	1100.53	1133.702	1162.361	1206.682	1348.035
10.00	1124.542	1099.571	1097.184	1137.75	1147.952	1191.934	1182.298
11.00	939.7979	919.1667	765.1041	950.5302	928.7509	990.4167	981.0354
12.00	1121.351	1100.374	732.851	1132.136	1147.932	1185.782	1176.232
13.00	1123.021	1089.5	740.5302	1112.165	1122.413	1182.272	1032.877
14.00	907.6667	1086.223	737.7802	1067.405	1072.804	1131.181	1039.712
15.00	769.8636	1085.631	888.0021	1101.005	1097.077	1142.003	1126.614
16.00	777.601	885.9469	1119.899	1093.928	1093.753	1113.044	644.8989
17.00	973.1157	648.9149	1116.434	1176.06	1151.563	1138.491	853.1094
18.00	1124.771	858.7185	1111.947	1199.389	1263.889	1276.979	1231.173
19.00	1114.25	965.5177	1096.622	1112.33	1128.829	1174.401	1164.797
20.00	1102.646	1103.447	939.7854	1108.063	1112.684	1134.869	1132.101
21.00	1106.048	1093.535	892.1939	1114.639	1111.535	1131.785	1061.85
22.00	1106.886	827.4911	1108.571	1114.982	1112.566	1125.366	1049.03
23.00	916.9698	675.0296	927.8535	825.0981	796.0577	757.625	729.3333
24.00	1104.76	732.601	1059.067	698.3272	678.1623	675.1419	1489.76

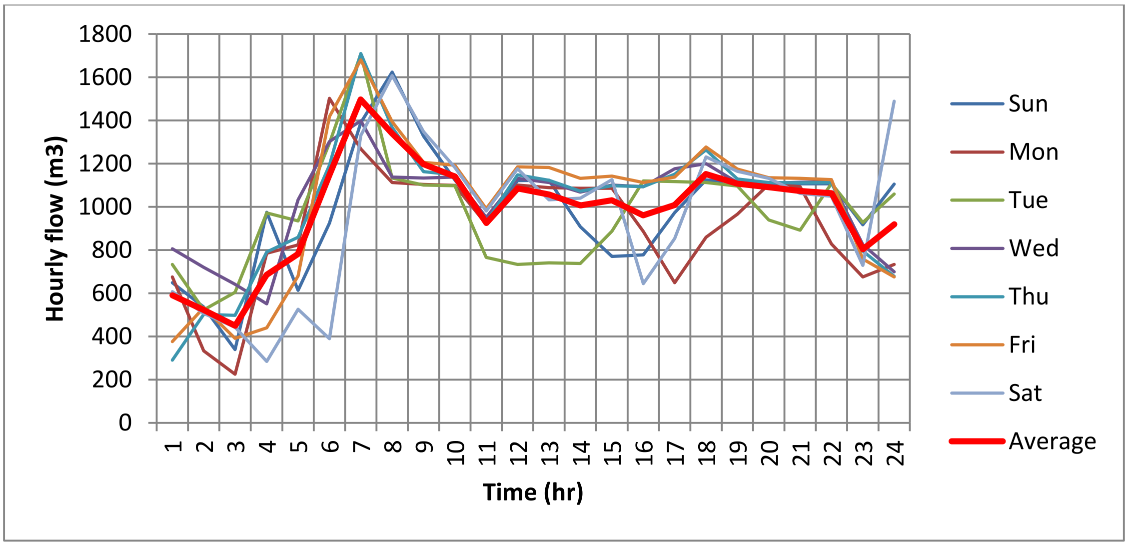


Table D-1 Hourly flow for the period of 2014 July 06 to 12

Time	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1.00	563.5168	736.1915	472.538	493.9258	594.0807	1002.962	454.3283
2.00	405.8547	780.0041	455.3329	482.437	492.562	477.8689	395.434
3.00	371.9436	405.5061	477.6342	434.2383	372.7525	410.4975	376.4014
4.00	630.374	676.8278	350.7037	598.5503	591.3369	297.4212	423.626
5.00	801.2906	665.5787	581.219	714.9532	658.1407	946.2952	438.564
6.00	965.1915	1508.176	1146.303	1081.957	1037.302	1070.719	416.692
7.00	1323.808	1562.181	1594.5	1631.299	1643.146	1497.356	1236.124
8.00	1496.654	1206.934	1437.986	1514.689	1539.065	1521.997	1379.522
9.00	1543.497	1201.367	1162.947	1176.149	1158.741	1176.962	1395.617
10.00	1204.076	1190.917	1152.321	1163	1160.194	1154.356	1453.347
11.00	964.1612	984.5708	948.5168	962.1718	950.5906	913.8132	1115.563
12.00	1166.7	1129.286	646.3013	1080.078	1043.717	1029.913	1184.949
13.00	1175.09	1103.493	494.3422	1070.233	1005.959	1026.468	1157.667
14.00	1154.833	1100.037	1040.968	1044.471	981.214	1025.302	1140.585
15.00	1148.167	1079.244	1068.877	1057.828	1012.598	1046.797	1085.258
16.00	1138.646	1037.608	1077.233	1015.204	1018.62	1046.534	1042.874
17.00	1138.833	1162.19	1087.659	1116.449	1100.374	1033.058	1113.141
18.00	1128.518	1326.559	1349.077	1291.706	1255.15	1175.737	1187.006
19.00	1123.596	1389.536	1335.366	1407.652	1399.485	1248.485	1210.029
20.00	1117.833	1227.196	1110.515	1212.722	1262.923	1164.541	986.6923
21.00	1115.101	1151.202	1118.846	1120.894	1105.854	1078.506	886.3086
22.00	1104.371	1131.102	1108.353	1101.846	1034.412	1086.785	979.9273
23.00	797.4607	814.0766	788.6272	743.5473	680.6776	760.6509	712.5279
24.00	707.8325	679.6558	657.7413	665.6472	678.7072	746.6951	837.2637

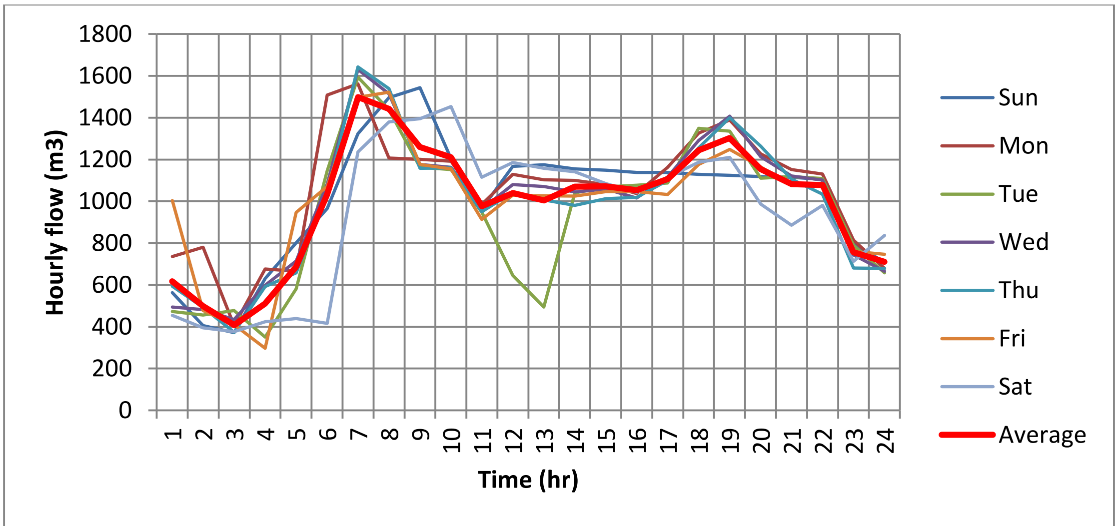
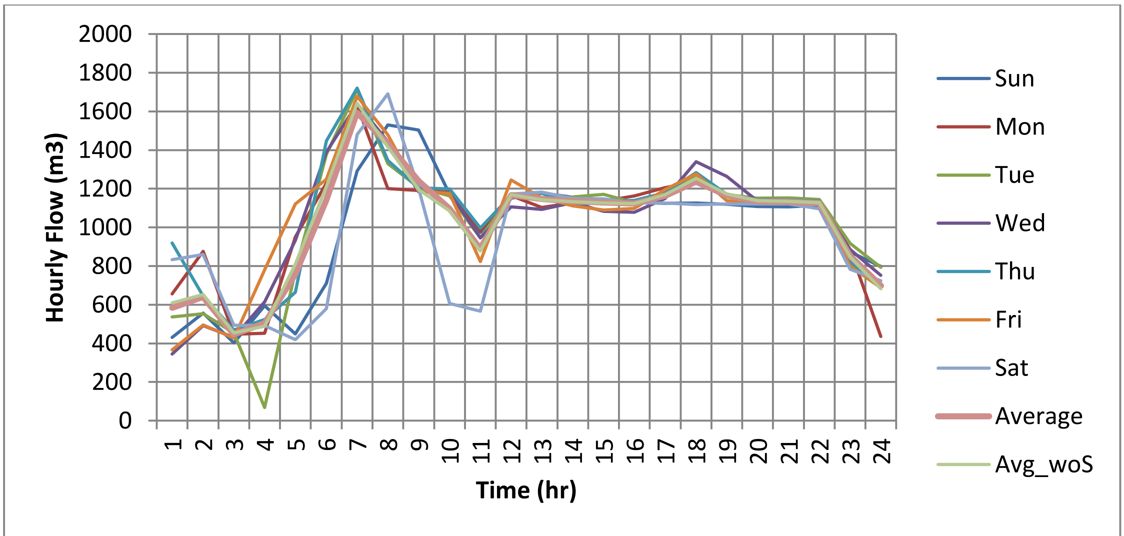


Table D-1 Hourly flow for the period of 2014 Oct 10 to 16

Time	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1.00	430.3668	656.3762	537.5551	344.9766	919.0782	366.4131	834.0589
2.00	557.2216	876.4461	552.9373	491.9558	645.3252	494.8343	859.8278
3.00	403.2195	448.031	454.4906	430.9553	469.7114	428.2887	493.0645
4.00	595.4203	453.1382	68.21399	615.3724	524.3572	780.498	491.5884
5.00	448.9644	951.4813	774.0223	932.9939	664.1112	1121.749	418.8461
6.00	711.0681	1228.74	1377.156	1388.766	1447.29	1249.093	579.2875
7.00	1291.911	1631.161	1712.514	1640.32	1720.01	1677.462	1480.397
8.00	1530.781	1200.684	1330.766	1444.199	1346.997	1479.271	1691.529
9.00	1504.003	1190.411	1207.218	1184.429	1204.437	1187.42	1202.988
10.00	1170.947	1183.379	1163.351	1178.886	1199.982	1176.167	606.6969
11.00	973.652	983.0177	945.5556	946.2983	997.8889	824.1522	567.399
12.00	1150.747	1164.118	1163.643	1107.158	1163.899	1246.005	1172.684
13.00	1177.651	1103.532	1145.844	1092.424	1175.871	1152.445	1182.454
14.00	1156.306	1128.244	1158.363	1128.226	1120.417	1112.005	1150
15.00	1142.566	1136.736	1171.25	1084.095	1132.413	1089.811	1148.078
16.00	1129.129	1162.25	1128.598	1078.853	1139.641	1097.78	1126.098
17.00	1123.907	1205.585	1162.491	1150.189	1179.302	1196.616	1125.634
18.00	1125.74	1236.253	1272.428	1339.437	1283.455	1276.178	1118.386
19.00	1119.705	1167.946	1169.6	1263.435	1171.683	1138.069	1121.583
20.00	1108.316	1140.571	1151.831	1136.013	1144.5	1133.851	1121.268
21.00	1106.573	1137.5	1152.614	1124.821	1140.97	1134.566	1122
22.00	1114.621	1133.482	1144.879	1126.833	1135.833	1130.369	1096.736
23.00	872.3346	886.6526	916.957	886.1728	821.1411	799.8179	782.8
24.00	797.7195	435.3718	793.6703	752.2731	702.5653	688.3127	723.5192



APPENDIX E

Sample of Spreadsheet development for model computation

Tower Level (m)	Inflow (Pumping) m3/hr	Nearest Low capacity	Nearest low capacity Level	Index	Nearest High Capacity	Nearest High capacity Level	Initial Storage (m3)	Storage at the end (m3)	Out flow (m3)
5.715	784	788.3	5	7	954	6	906.8	896.05	141.4
5.65	848	788.3	5	7	954	6	896.0	865.0	172.3
5.463	912	788.3	5	7	954	6	865.0	924.3	92.7
5.821	976	788.3	5	7	954	6	924.3	923.0	164.0
5.813	1040	788.3	5	7	954	6	923.0	859.7	236.6
5.431	1104	788.3	5	7	954	6	859.7	750.7	293.0
4.773	1168	622.6	4	6	788.3	5	750.7	886.6	58.8
5.593	1102	788.3	5	7	954	6	886.6	867.8	202.4
5.48	1036	788.3	5	7	954	6	867.8	718.4	322.2
4.578	971	622.6	4	6	788.3	5	718.4	742.6	137.6
4.724	905	622.6	4	6	788.3	5	742.6	744.0	149.3
4.733	839	622.6	4	6	788.3	5	744.0	678.1	205.8
4.335	773	622.6	4	6	788.3	5	678.1	570.4	236.5
3.685	835	456.9	3	5	622.6	4	570.4	462.7	246.9
3.035	898	456.9	3	5	622.6	4	462.7	318.9	293.4
2.369	960	207.4	1.775	3	395	2.775	318.9	187.6	291.2
1.63	1022	70.9	0.775	2	207.4	1.775	187.6	148.8	209.2
1.346	1085	70.9	0.775	2	207.4	1.775	148.8	107.7	221.9
1.045	1147	70.9	0.775	2	207.4	1.775	107.7	63.6	235.3
0.696	1147	0.0	0.001	1	70.9	0.775	63.6	33.1	221.6

0.363	1147	0.0	0.001	1	70.9	0.775	33.1	21.2	203.0
0.233	1147	0.0	0.001	1	70.9	0.775	21.2	22.0	190.4
0.241	1146	0.0	0.001	1	70.9	0.775	22.0	22.7	190.3
0.249	1146	0.0	0.001	1	70.9	0.775	22.7	7.1	206.6
0.079	1146	0.0	0.001	1	70.9	0.775	7.1	0.5	197.7
0.006	1142	0.0	0.001	1	70.9	0.775	0.5	1.2	189.6
0.014	1138	0.0	0.001	1	70.9	0.775	1.2	0.5	190.3
0.006	1134	0.0	0.001	1	70.9	0.775	0.5	0.5	188.9
0.006	1129	0.0	0.001	1	70.9	0.775	0.5	0.5	188.2
0.006	1125	0.0	0.001	1	70.9	0.775	0.5	0.5	187.5
0.006	1121	0.0	0.001	1	70.9	0.775	0.5	1.2	186.1
0.014	1121	0.0	0.001	1	70.9	0.775	1.2	1.9	186.0
0.022	1120	0.0	0.001	1	70.9	0.775	1.9	0.5	188.1
0.006	1120	0.0	0.001	1	70.9	0.775	0.5	0.5	186.6
0.006	1119	0.0	0.001	1	70.9	0.775	0.5	0.5	186.5
0.006	1119	0.0	0.001	1	70.9	0.775	0.5	0.5	186.4
0.006	1118	0.0	0.001	1	70.9	0.775	0.5	0.5	186.3
0.006	1117	0.0	0.001	1	70.9	0.775	0.5	0.5	186.2
0.006	1116	0.0	0.001	1	70.9	0.775	0.5	0.5	186.1
0.006	1116	0.0	0.001	1	70.9	0.775	0.5	0.5	185.9
0.006	1115	0.0	0.001	1	70.9	0.775	0.5	0.5	185.8
0.006	1114	0.0	0.001	1	70.9	0.775	0.5	0.5	185.6
0.006	1113	0.0	0.001	1	70.9	0.775	0.5	0.5	185.5

0.006	1112	0.0	0.001	1	70.9	0.775	0.5	0.5	185.3
0.006	1110	0.0	0.001	1	70.9	0.775	0.5	0.5	185.1
0.006	1109	0.0	0.001	1	70.9	0.775	0.5	0.5	184.8
0.006	1108	0.0	0.001	1	70.9	0.775	0.5	1.2	183.9
0.014	1106	0.0	0.001	1	70.9	0.775	1.2	0.5	185.1
0.006	1105	0.0	0.001	1	70.9	0.775	0.5	0.5	184.2
0.006	1107	0.0	0.001	1	70.9	0.775	0.5	0.5	184.4
0.006	1108	0.0	0.001	1	70.9	0.775	0.5	0.5	184.7
0.006	1110	0.0	0.001	1	70.9	0.775	0.5	9.3	176.1
0.103	1112	0.0	0.001	1	70.9	0.775	9.3	20.5	174.1
0.225	1115	0.0	0.001	1	70.9	0.775	20.5	23.5	182.8
0.258	1115	0.0	0.001	1	70.9	0.775	23.5	28.7	180.7
0.314	1115	0.0	0.001	1	70.9	0.775	28.7	27.9	186.6
0.306	1115	0.0	0.001	1	70.9	0.775	27.9	29.5	184.3
0.323	1115	0.0	0.001	1	70.9	0.775	29.5	24.3	191.1
0.266	1115	0.0	0.001	1	70.9	0.775	24.3	21.2	188.9
0.233	1115	0.0	0.001	1	70.9	0.775	21.2	19.8	187.3
0.217	1109	0.0	0.001	1	70.9	0.775	19.8	18.3	186.4
0.201	1105	0.0	0.001	1	70.9	0.775	18.3	13.8	188.7
0.152	1102	0.0	0.001	1	70.9	0.775	13.8	10.8	186.6
0.119	1099	0.0	0.001	1	70.9	0.775	10.8	5.7	188.4
0.063	1098	0.0	0.001	1	70.9	0.775	5.7	0.5	188.2
0.006	1081	0.0	0.001	1	70.9	0.775	0.5	0.5	180.2

0.006	1083	0.0	0.001	1	70.9	0.775	0.5	0.5	180.5
0.006	1086	0.0	0.001	1	70.9	0.775	0.5	0.5	180.9
0.006	1088	0.0	0.001	1	70.9	0.775	0.5	0.5	181.3
0.006	1090	0.0	0.001	1	70.9	0.775	0.5	0.5	181.7
0.006	1092	0.0	0.001	1	70.9	0.775	0.5	0.5	182.1
0.006	1094	0.0	0.001	1	70.9	0.775	0.5	0.5	182.4
0.006	1097	0.0	0.001	1	70.9	0.775	0.5	0.5	182.8
0.006	1100	0.0	0.001	1	70.9	0.775	0.5	0.5	183.3
0.006	1102	0.0	0.001	1	70.9	0.775	0.5	0.5	183.7
0.006	1104	0.0	0.001	1	70.9	0.775	0.5	0.5	184.0
0.006	1105	0.0	0.001	1	70.9	0.775	0.5	0.5	184.2
0.006	1107	0.0	0.001	1	70.9	0.775	0.5	0.5	184.4
0.006	1113	0.0	0.001	1	70.9	0.775	0.5	0.5	185.5
0.006	1113	0.0	0.001	1	70.9	0.775	0.5	0.5	185.5
0.006	1113	0.0	0.001	1	70.9	0.775	0.5	0.5	185.5
0.006	1113	0.0	0.001	1	70.9	0.775	0.5	0.5	185.5
0.006	1113	0.0	0.001	1	70.9	0.775	0.5	0.5	185.5
0.006	1113	0.0	0.001	1	70.9	0.775	0.5	0.5	185.5
0.006	1114	0.0	0.001	1	70.9	0.775	0.5	1.2	184.9
0.014	1114	0.0	0.001	1	70.9	0.775	1.2	3.4	183.4
0.038	1113	0.0	0.001	1	70.9	0.775	3.4	0.5	188.5
0.006	1113	0.0	0.001	1	70.9	0.775	0.5	17.5	168.5
0.192	1113	0.0	0.001	1	70.9	0.775	17.5	37.6	165.3

0.412	1113	0.0	0.001	1	70.9	0.775	37.6	60.0	163.1
0.656	1112	0.0	0.001	1	70.9	0.775	60.0	88.9	156.4
0.907	1112	70.9	0.775	2	207.4	1.775	88.9	117.7	156.5
1.118	1112	70.9	0.775	2	207.4	1.775	117.7	145.4	157.5
1.321	1111	70.9	0.775	2	207.4	1.775	145.4	176.6	154.1
1.549	1111	70.9	0.775	2	207.4	1.775	176.6	205.4	156.4
1.76	1111	70.9	0.775	2	207.4	1.775	205.4	242.7	147.9
1.963	1111	207.4	1.775	3	395	2.775	242.7	287.0	140.9
2.199	1111	207.4	1.775	3	395	2.775	287.0	326.5	145.6
2.41	1112	207.4	1.775	3	395	2.775	326.5	370.6	141.2
2.645	1112	207.4	1.775	3	395	2.775	370.6	417.3	138.6
2.856	1112	395.0	2.775	4	456.9	3	417.3	474.8	127.8
3.108	1112	456.9	3	5	622.6	4	474.8	523.3	136.8
3.401	968	456.9	3	5	622.6	4	523.3	574.4	110.2
3.709	823	456.9	3	5	622.6	4	574.4	635.0	76.5
4.075	679	622.6	4	6	788.3	5	635.0	699.6	48.5
4.465	534	622.6	4	6	788.3	5	699.6	766.9	21.8
4.871	390	622.6	4	6	788.3	5	766.9	770.9	61.0

APPENDIX F

Field survey results

Water Supply Service Level Monitoring at Household Level – Maharagama Water Supply Scheme 2015

Under the framework of Study of water demand and level of service, this survey is aimed to collect and monitor water supply level of service at household level across Maharagama water supply area. This survey is conducted by the MSc students of University of Moratuwa in collaboration with the NWSDB Maharagama. The Information gathered will only be used for the said academic purposes and will remain strictly confidential.

General Information

Account Number		
Household Type (Number of storey)	Single	
	Two	
	Three or above	
Number of residents		

Water Availability

How many days you get water during the week	Poor	
	Good	
At what time do you get water during the day	Very poor	
	Poor	
	Ok	
	Good	
Is the water you getting enough to satisfy your need	Yes	No
How many liters of water storage capacity you have		

Service level

How is the service you get	Excellent	
	Good	
	Acceptable	

	Unacceptable	
If unacceptable, what are the reasons for the poor service level in your opinion		
Suggestions to improvements		

Water Supply Service Level Monitoring at Operational Level – Maharagama Water Supply Scheme 2015

Under the framework of Study of water demand and level of service, this survey is aimed to collect and monitor water supply level of service at Zone level across Maharagama water supply area. This survey is conducted by the MSc students of University of Moratuwa in collaboration with the NWSDB Maharagama. The Information gathered will only be used for the said academic purposes and will remain strictly confidential.

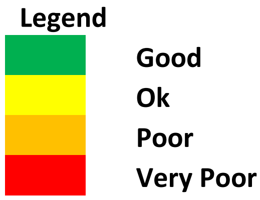
General Information

Zone code/Docket numbers		
Overall Status of service	Excellent	
	Good	
	Acceptable	
	Unacceptable	

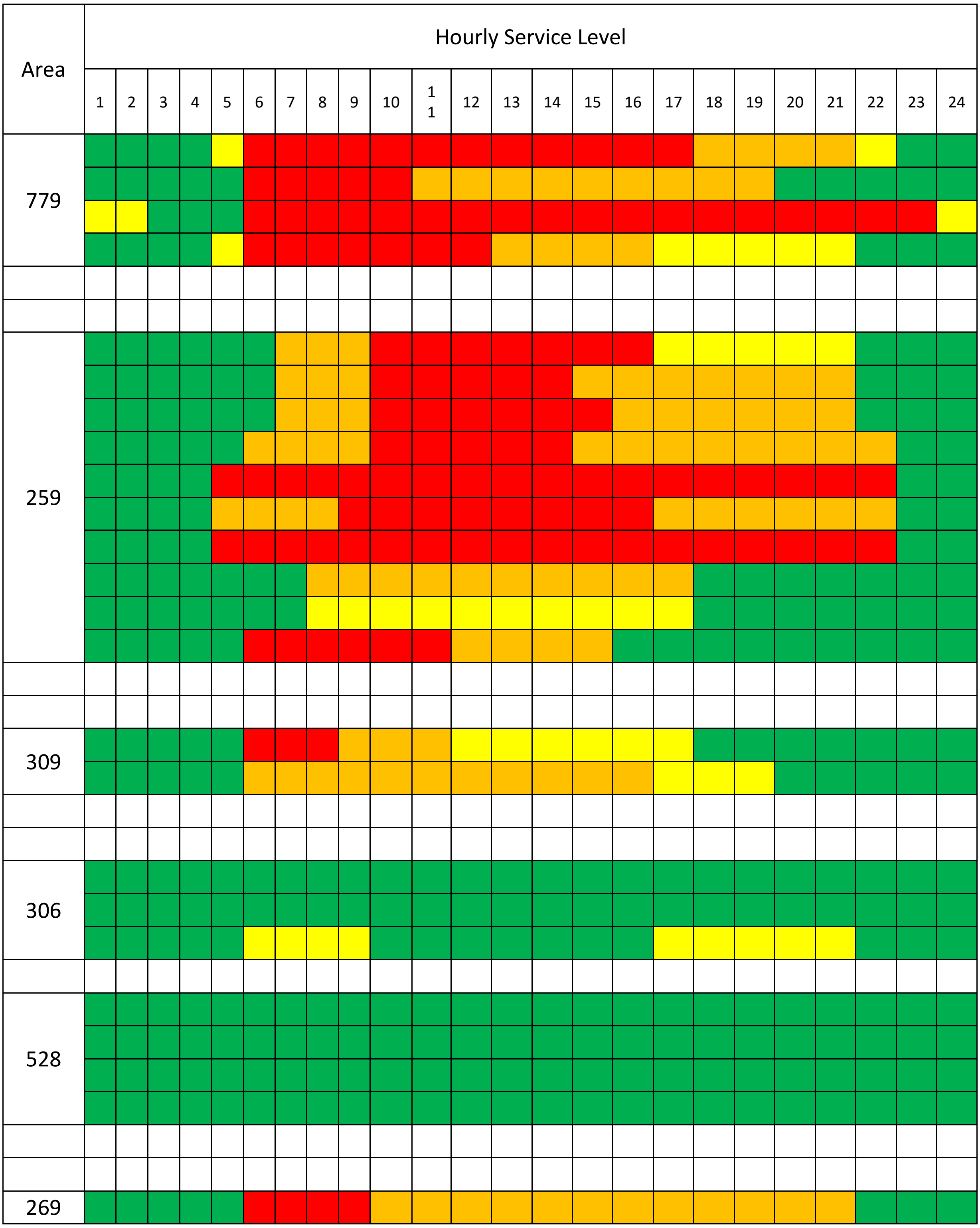
Level of Service

What are the problem areas you identified	(Docket numbers)		
Types of problems	Low pressure		
	Curtailed Supply		
	Frequent leaks		
What are the Specific durations for those problems	Low pressure	6 to 9	
		10 to 17	
		18 to 21	

		22 to 5	
	Curtailed Supply	6 to 9	
		10 to 17	
		18 to 21	
		22 to 5	
	Frequent leaks	6 to 9	
		10 to 17	
		18 to 21	
		22 to 5	
What are reasons for said problems in your opinion			
Since how long these problems been there			
Suggestions to improvements			



Diurnal level of service for sample areas



783																								
787																								
285																								
530																								
760																								